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Issue of Journal. The Journal appears in four parts per sessional volume, viz. in January, April, July and October. A brochure describing the origin, progress and purposes of the Institution, and comprising also the Memorandum and Articles of Association, the By-Laws and Regulations of the Institution, the Library Catalogue to date (with subject index), and the List of Members, was published in September, 1915, to be followed periodically by revisions of the Library Catalogue and List of Members. The List of Members brought up to March, 1921, is now issued.

Members of all classes are entitled to receive these publications free: for additional copies of the Journal they will be charged at the price of seven shillings and sixpence per part, and of the brochures at the prices stated on the wrappers, varying in proportion to bulk.

Changes of Address. It is particularly requested that members notify the Secretary immediately of any change of address; and members are also requested to advise the Parcel Post Department as well as the Letter Office, of any temporary change of address, as, unless this is done, parcel post packets will not be re-addressed; but will be returned to the offices of the Institution in London, thus incurring further expense for postage.

To Authors of Papers. Papers should be written in the third person, and the copy should be carefully corrected by the author before it is presented.

All drawings, diagrams or other illustrations should be sent in a fit state for direct photographic reproduction.

All quotations, technical terms, and localisms should be indicated by means of inverted commas.

Foreign weights, measures, and costs should be given whenever possible, and also their English equivalents.

It is suggested that authors append as complete a bibliography of the subject treated as may be possible.

All papers and notes submitted to the Institution are supposed to be original communications unless distinctly stated to be otherwise, in which case the exact reference to the previous publication should be given.

Communications upon papers read at meetings, notices of personal movements, or other matter for which publication is desired in the next issue of the Journal, should be in the hands of the Editor on or before the last day of December, March, June or September as the case may be. Subsequent delivery may be too late for insertion.

The Council desire to draw the attention of authors to the serious increase in the cost of production. Papers, both for the Journal and for communication to the Institution, should be as concise and condensed as possible.

Communications. The Council invite members to submit papers for the forthcoming session. Communications to the Institution will, subject to the approval of the Publication Committee, be published in the Journal.

Appointments Register. A Register will be kept at the Offices of the Institution for the convenience of firms requiring the services of members and for members requiring appointments, but on the distinct understanding that the Institution accepts no responsibility and gives no guarantee.

Library. The Institution's Library is in course of reorganization in the new premises at No. 5 John Street, Adelphi, and may be consulted between 11 and 4 daily. Extensive additions are being made to the current and standard literature on Petroleum.

Additions since publication of last Journal.

From Department of Interior, U.S. Geological Survey :—

Water supply, Paper 500 A. Cœur D'Alene Lake, Idaho, and the Overflow Lands. By R. W. Davenport.

Report. Asbestos in 1919. By J. S. Driller.

Report. Coal in 1918. Part B. Distribution and Consumption. By C. E. Lesher.

Report. Fuller's Earth in 1919. By Jefferson Middleton.

Report. Sand-Lime Brick in 1919. By Jefferson Middleton.

Report. Magnesite in 1919. By Charles G. Yale and Ralph W. Stone.

Report. Phosphate Rock in 1919. By Ralph W. Stone.

Bulletin 716 H. Character of Coal in the Thomas Bed near Harrison, West Virginia. By Marius R. Campbell.

Bulletin 716 G. Coal in the Middle and Eastern Parts of San Juan County, New Mexico. By Clyde M. Bauer and John B. Reeside, Jun.

Bulletin 715 K. The Divide Silver District Nevada. By Adolph Knopf.

Bulletin 715 L. The Mogollon District, New Mexico. By Henry G. Ferguson.

Bulletin 713. Geography, Geology, and Mineral Resources of the Fort Hall Indian District Reservation, Idaho. By G. R. Mansfield. (With Chapter on Water Resources. By W. B. Heroy.)

Water Supply, Paper 456. Surface Water Supply of the United States, 1917. Part VI. Missouri River Basin. By N. C. Grover, W. A. Lamb, and R. Follansbee.

Professional, Paper 129 A. Lithologic Subsurface Correlation in the "Bend Series" of North-Central Texas. By Marcus I. Goldman.

From the Department of Interior, Bureau of Mines :—

Some Principles Governing the Production of Oil-wells. By Carl H. Beal and J. O. Lewis.

From the Ministry of Finance, Egypt :—

Petroleum Research Bulletin No. 1.

Preliminary Government Report on Abu Durba (Western Sinai). By W. F. Hume, A.R.S.M., etc.; T. G. Madgwick, M.Inst.M.M., etc.; F. W. Moon, B.E., A.M.Inst.C.E., etc.; H. Sadek, B.Sc., F.G.S.

From Department of Mines, Geological Survey, Canada :—

Summary Report, 1919, Part A.

Summary Report, 1920, Part B.

Summary Report, 1920, Part E.

Bulletin No. 32. Inyoite from New Brunswick. By Eugene Poitevin and H. V. Ellsworth.

Purchased :—

Field Mapping for the Oil Geogolist. By C. A. Warner.

The attention of members is drawn to the new supplement of the Journal which deals with current Petroleum literature. To make this section of the maximum usefulness it is necessary that there

should be full co-operation between chemists, engineers and geologists, and that matter which has inadvertently escaped notice shall be immediately sent in to the Editor. The Institution has been indebted to Mr. Andrew Campbell for the compilation of the bibliography during this past session, and is now under similar obligation to Mr. W. J. Wilson.

Advertisements in the Journal. A limited number of Advertisements of firms interested in the Petroleum Industry may be inserted in the Journal. Application for terms, etc., should be made to the Secretary.

LIST OF ADVERTISERS.

(Members are desired, when making enquiries or placing orders with advertisers, to mention that they have seen their announcement in the Journal.)

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PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that Members of the Institution send information regarding their movements to the Secretary for insertion under this heading.

Mr. GEORGE HOWELL having relinquished the post of Secretary has returned to his profession as Consulting Petroleum Engineer and Geologist.

Mr. PERCY R. CLARK, late of Baku, Russia, is shortly visiting Germany and Austria.

Mr. C. B. ROSENPLAENTER, who returned from the United States in July, has, with the consent of the Supreme Court of the State of New York, changed his name to C. B. McKeever.

Mr. J. E. MARSHALL HALL informs us that he is leaving for Africa.

Mr. C. B. MCKEEVER informs us that he is leaving for Central America.

Mr. J. A. CHILD has left for Bolivia.

Mr. W. J. WIGNEY is now Assistant London Manager to the National Supply Corporation of 165 Queen Victoria Street, E.C. 4.

Capt. R. G. STICKLAND is now in England, having returned from Miri, Sarawak.

Dr. THOLE has been appointed to represent the Institution on the Viscosity Panel of the B.E. Standards Association.

ON the recommendation of a Sub-committee of the Council, appointed to investigate the internal administration of the Institution, it was decided to combine the offices of Librarian and Secretary. As a result Mrs. A. L. Eastlake and Mr. Howell have ceased to act in these capacities. The thanks of the Institution are due to them for their loyal and enthusiastic service. To Mrs. Eastlake fell the opportunity of reorganizing the Library—*quis monumentum . . . circumspice.* Her devotion to the Institution, the living memoir of her late chief, is known to all of us and our best wishes go with her.

CORRESPONDENCE.

To the Editor.

DEAR SIR,

It is with great regret that owing to a change of policy, and the combining of the office of Librarian and that of Secretary, I am severing my connection with the Institution with which I have been closely connected since its inception.

So many of the members both here and abroad have been and still are such old personal friends of mine that I feel I should like to say "good-bye" and thank them for their friendship and support through the medium of the Journal.

The loyalty and help of my member friends, including yourself, when the Founder and First President of this Institution passed to his well-earned rest, will never be forgotten.

Yours sincerely,

E. EVELYN EASTLAKE.

SPECIFICATIONS.

We have received the List of British Standard Specifications and Reports from the British Engineering Standards Association, including a number of matters of interest to the petroleum profession. Copies may be had from 28 Victoria Street, Westminster, London, S.W.1.

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS.

The Board of Directors of the American Institute of Mining and Metallurgical Engineers of 29 West 39th Street, New York, and the Council of the Institution of Petroleum Technologists, have entered into a mutual understanding whereby any Technologist being a Member of either Society, possessing the necessary qualifications and desiring to become Member of the Institution or Institute respectively, can apply to the Institution or Institute, and the respective Council's recommendation will be accepted from him in lieu of signatures on an application form duly signed by Members. This arrangement does not in any way modify or do away with the regulations and rights governing election of members by the respective Institute or Institution.

COMMITTEE ON STANDARDIZATION AND NOMENCLATURE.

The Council of the Institution has appointed a Standing Committee to deal with the standardization of tests relating to mineral oils and the nomenclature of naphthology. The Committee is to possess wide powers of co-option and will undoubtedly ask for the assistance and co-operation of those members of the Institution who have special acquaintance with the multifarious tests and estimations now current. Sub-committees will be appointed to deal with groups of tests, and an attempt will be made to put forward an authoritative series of methods of analysis. The urgent need for such work is felt in other countries, and the excellent work already carried out in the United States needs no mention here. On another page of this issue of the Journal it will be noticed that further efforts are being initiated in America.

Members will be kept in touch with the Committee's activities by means of periodical reports in the Journal.

CRYSTAL PALACE LECTURES ON PETROLEUM.

The Council have arranged to publish in book form a complete series of the Crystal Palace Lectures, which will be rewritten and illustrated with some ninety-two diagrams and plates. The work is to be issued as a Popular Petroleum Book for the general petroleum-reading world, with glossary, statistical tables (including various weights and measures for technical reference), a bibliography and other useful information. The Council are anxious that the members should support this venture, and those members desiring to subscribe to the volume can obtain further information on application to the Secretary.

At the moment of writing, the book is in the Press and should be available early in the New Year.

List of Contributors.

Introductory	Sir FREDERICK BLACK.
Romance of Petroleum	The late Sir BOVERTON REDWOOD, Bart.
Wild Catting	E. H. CUNNINGHAM CRAIG.
Prospecting	G. HOWELL.
Drilling	H. MAY.
Transport and Storage	H. BARRINGER.
Refining	A. E. DUNSTAN.
Chemistry of Petroleum	F. B. THOLE.
Utilization of Light Oil	W. ORMANDY.
,, Heavy Oil	J. S. S. BRAME.
Nomenclature	J. KEWLEY.
Statistics, etc.	ARTHUR W. EASTLAKE.

PETROLEUM NOTES AND CORRESPONDENCE.

It has been decided to open columns in the Journal to be devoted to general petroleum notes and to correspondence. Members of the Institution are invited to contribute thereto as occasion warrants.

THE NATIONAL SUPPLY CORPORATION.

The National Supply Corporation, the well-known manufacturers of oil, gas and water well-drilling machinery and equipment, have opened offices at 165 Queen Victoria Street, London, E.C.4. From this office

will be conducted all business connected with the British and Foreign oil companies operating in all fields outside the United States of America.

Mr. Leroy V. Boggs, an official of the Corporation, has arrived in London to establish this new organization. Mr. Boggs is by no means a stranger to the British oil fraternity, having been in London on many previous occasions. He has also travelled extensively throughout the oil-fields of the world, and has specialized in oil technology for a number of years.

Mr. T. F. Hudgins, B.M.E., E.E., formerly Professor of Engineering at Purdue University, and later, Field Technical Adviser to the National Supply Companies, has been appointed Manager. Mr. Hudgins is an expert in the methods of production, refining and distribution of petroleum, and has made a special study of the extraction of petrol from natural gas. Mr. William J. Wigney, A.M.Inst.P.T., previously connected with the Shell in Egypt, has been engaged as Assistant London Manager.

As announced some months ago, the National Supply Corporation have acquired the Union Tool Co. and its associates, thereby becoming the largest manufacturers of oil-field equipment in the world. The extension of their organization to London will enable them to render a very efficient service to the British oil companies, and keep the latter fully advised as to developments connected with all engineering branches of the petroleum industry.

The National Supply Corporation has fully recognized the need in Europe of a centre to which the various European oil companies can approach for practical advice relating to the technical problems of petroleum mining. The technical staff of the National Supply Corporation and a unique collection of technical data and drawings are placed free at the disposal of interested persons. Not only can advice on the latest drilling methods and equipment be obtained, but also expert information regarding production, refining, extraction of petrol from natural gas, transportation and storage of petroleum.

RESEARCH COMMITTEE.

A Joint Research Committee has just been formed by the National Benzole Association and the University of Leeds for the purpose of carrying out research into the production and use of benzole and its

homologues. The Association is concerned with the production of crude and refined benzole for use as motor spirit or in any other way, and according to its constitution one of its objects is to carry on, assist, and promote investigation and research. The term "benzole" is used in the widest sense to cover benzene, toluene, and other substances which enter into the constitution of motor spirit. The whole of the carbonization industries of the country, including primarily by-product coke oven plants and gasworks are interested in the objects of the Association, which has, therefore, a wide and influential membership. The variety of carbonization and gasification processes coming into operation at the present time, each with its own conditions of operation, in addition to what may be called the standardized methods of production of the by-product coke oven and ordinary carbonization plant, taken in conjunction with the increasing demand for light oil in the States and other petroleum-producing countries and the consequent limitation of their capacity for export, make it very necessary from several points of view that this country should place itself in as strong a position as possible with regard to the home production of light oil and motor spirit. It is believed that one of the best ways of doing so will be to investigate the chemical possibilities in this direction of our home industries and to utilize the by-products obtainable from coal to the fullest advantage. To do so adequately requires investigation on a more extended scale, and the commercial enterprises concerned have plenty of work of this kind before them. There are many important problems, however, which, concerning the industry as a whole, can, it is believed, be best attacked by joint action. In this case, not only members of the Association drawn directly from the industry, but members of the staff of Leeds University occupied with cognate matters, are to enter into co-operation. In doing so, they are following the precedent which has been established already by the University of Leeds and the gas industry, in the formation of the Joint Research Committee which has now been in existence for a number of years for the investigation of the problems of the gas industry, and which has published a number of reports bearing on these problems. The new Committee will be constituted on similar lines with equal representation from the University and the Association. Work will be carried out under the direction of the Committee and the supervision of Professor Cobb on problems of importance and urgency, and reports will be

published at intervals embodying the results. The initial membership of the Joint Committee is given below :—

J. W. Cobb, C.B.E., B.Sc., Professor of Coal-Gas and Fuel Industries.
J. B. Cohen, B.Sc., Ph.D., F.R.S., Professor of Organic Chemistry.
A. G. Perkin, F.R.S., Professor of Colour Chemistry and Dyeing.
Granville Poole, B.Sc., M.I.Min.E., F.G.S., Professor of Mining.
A. Smithells, C.M.G., B.Sc., F.R.S., Professor of Chemistry and Pro-Vice-Chancellor of the University.
W. G. Adam, B.A.(Oxon.), F.C.S.
T. Howard Butler, Ph.D., M.Sc., F.I.C.
S. Henshaw, F.I.C.
S. A. Sadler.
E. W. Smith, D.Sc., F.I.C.

REVIEW.

"Field Mapping for the Oil Geologist." By C. A. WARNER. (*John Wiley & Sons, New York; Chapman & Hall, Ltd., London.*)

This is an eminently practical and useful little book, written for practical men by one who evidently knows his subject.

It deals entirely with American conditions, and the methods that are used in American oil-fields, that is to say in open ground, or at least ground that is not densely wooded and obscured.

It will be an invaluable book for the "instrument man" or the surveyor-assistant to a geologist, and will teach him how to make maps with great accuracy. The part dealing with subsurface maps and convergence sheets is particularly good.

Even for the experienced geologist there are several hints that will be found useful, especially if he should have to undertake the somewhat mechanical work of contouring a producing sand in a developed field, but it is chiefly by beginners and surveyors rather than geologists that the value of the work will be appreciated.

The book is well and clearly illustrated, and there are some very handy tables in the latter part. The vertical section of geological formations in the different fields extracted from the *Bulletin* of the United States Geological Survey will be of great value to any geologist who may have to study these regions.

E. H. C.

PAPERS WHICH HAVE BEEN READ BEFORE THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

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John Wells	Initial Equipment and Organization as Affecting the Ultimate Success of Oil Companies	2
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Sir John Cadman	Notes on the Development of the Trinidad Oil-fields	3
E. H. Cunningham Craig	The Prospective Oil-fields of Western Canada	3
W. A. Hall	The "Cracking" of Oils with a view to obtaining Motor Spirit and other Products	3
Prof. V. B. Lewes	The Chemistry of the "Cracking" of Heavy Oils	3
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William Calder	Oil-well Engineering	4
H. Barringer	The Evolution of the Oil Tank-Ship	4
P. C. A. Stewart	The Petroleum Industry of Mexico	5
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Members requiring the Journal bound should communicate with our printers, Messrs. Wm. Brendon & Son, Ltd., Plymouth, who will undertake the work according to requirements at most reasonable prices.

The Fifty-Fifth General Meeting of the Institution was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C., on Tuesday evening, April 19th, 1921. Sir Frederick W. Black, K.C.B., retiring President, occupied the Chair at the commencement of the meeting.

The Members of Council present were Sir F. W. Black, Sir John Cadman, Mr. H. Barringer, Dr. Ormandy, Mr. Cunningham Craig, Mr. Arthur W. Eastlake, Mr. J. Kewley, and Professor Brame in the Chair.

The Retiring President, at the opening of the meeting, said it was his duty to ask the members to perform the function of welcoming the incoming and speeding the outgoing President. In the course of a few minutes it would be his duty to descend from the lofty pedestal he at present occupied to the floor of the house, where he hoped that in the future he would not be altogether a silent member. He had now to divest himself of all the honours, privileges and responsibilities of the presidency of the Institution. He said with all sincerity that he regarded it as a very great and distinguished honour to have been the President of the Institution for the past two years. The times had been propitious, because with the greater interest taken in petroleum and education in petroleum technology the Institution had been on the up-grade all the time. The outgoing President took no credit to himself for that state of affairs; it was due to the good work of the various members of the Institution and to the fact that the times had been favourable. He desired to say a few words in regard to the credit that was due to the members for the position in which the Institution found itself at the present time, and in that connection he wished to repeat some words that were said to him by a man who always meant what he said and said what he meant, who never indulged in vain and empty compliments and who was a very good judge on this particular subject. His friend, Mr. J. C. Clarke of the Petroleum Department, told him that he used to look in at the meetings of the Institution during the war and that he was filled with very great admiration for the way in which the faithful and sometimes small band kept the flag flying in days that were dark and trying. It was that work which kept the Institution alive. The members attended the meetings at times when it was not particularly pleasant to venture out into the streets at all, when Zeppelins and other aircraft were about. But that kept the flag of the Institution flying, and it was to those who did that work that the credit belonged for the position in which the Institution found itself at the present time, with a prospect before it of usefulness a

hundredfold larger than it had already accomplished. That was all he desired to say in regard to the past, except to thank every member of the Council and of the Institution for the very cordial co-operation and assistance he had received from them. The whole duty of the President had been a pleasure. His only regret was that time and other calls did not permit him to give more attention to the affairs of the Institution. It was not merely attendance at the Council meetings and the meetings of the Institution, but a great deal of thought that was required in regard to the spheres of activity that might be adopted.

It was now his duty to welcome to the Chair the new President, Professor Brame. Professor Brame was well known to all the members as one of the Institution's ablest speakers and wisest counsellors. He was sure that at the end of his period of office Professor Brame would be able to say exactly what he himself was saying at the present time—that he had received the most cordial assistance and kindness from the members, and that he had seen the Institution advancing even more rapidly than it had done during his predecessor's period of office. He could say with confidence that when Professor Brame came to the end of his term of office the members would be able to say that it stood on a level with the best record of any of the previous Presidents. He had much pleasure in welcoming Professor Brame to the Chair and asking him, as was said in the Navy and Army, "to carry on."

The Chair was then vacated by Sir Frederick Black and taken, amid hearty cheering, by Professor Brame.

The President (Professor J. S. S. Brame) thanked the Council for the honour they had done him in electing him President. He had had some diffidence in accepting the office, because he had some doubts as to his suitability for it, as his connection with the industry was largely academic. All he could offer to the Institution in return for the honour was a determination to do all in his power, both in the Institution and outside it, to further its interests and objects, and to devote his best energies, coupled with a somewhat progressive spirit, to its service. Momentous events in the history of the Institution were foreshadowed in the recommendations of the Committee appointed as the result of the recent Special Meeting. He was fully in sympathy with every effort to obtain greater personal interest and activity on the part of the general body of the members, and in other directions which had been often mooted at the meetings he might promise enthusiastic co-operation. First and foremost there was the development of the Institution so that it might become the recognized authority on petroleum questions, and that in not too restricted a sense of the word "petroleum." Further, there was the closer association with education of petroleum technologists, a direction in which his training and

experience might perhaps be of better service to the Institution than in other directions. There were the large and important questions of standardization of specifications and testing methods. Those could only be satisfactorily dealt with in co-operation with other bodies in the United States and elsewhere, and he hoped it would be possible during his term of office to arrange such co-operation and begin that important work.

He proposed on the present occasion to break away from the precedent set by his two immediate predecessors in the Chair and not give a Presidential Address. At the recent Special Meeting Sir Frederick Black expressed the opinion that there should be more frequent opportunities for members to offer suggestions for the advancement of the Institution and possibly to criticize the general policy of the Council. He fully concurred, and suggested that the Annual General Meeting should afford the opportunity for a heart-to-heart talk. Hitherto, however, that meeting had always been held at the very inconvenient hour of twelve-thirty, and was purely formal and therefore but scantily attended. He sincerely hoped that the Annual General Meeting would become a live meeting; it should be something more than the mere formal business meeting of the year. For that reason it must be held at an hour convenient to the general body of members, and he would suggest that at such meeting the President's address should follow the ordinary routine business. Such procedure was usual with most scientific and technical societies. He could not hope that, although he might have the honour to read an address at the next Annual General Meeting, it would offer any inducement to members to attend—it might even defeat the object he had in view by keeping them away—but he felt confident that many of his successors in the office of President would be men of such ability and distinction that their addresses would command attendances exceeding those of the ordinary meetings.

It only remained for him to undertake the most pleasing duty of the incoming President, the proposal of the thanks of the Institution to the retiring President, Sir Frederick Black. He was sure that every member would agree with him that Sir Frederick's two years in the Presidential Chair had been of immense benefit to the Institution. Many of the members had perhaps seen little beyond his able and eloquent conduct of the ordinary proceedings, but those who had had the pleasure of serving under him on the Council realized with what business aptitude and genial manner he had presided at the meetings and what energy he had bestowed upon the affairs of the Institution. There was no need for him to say anything of Sir Frederick's distinguished career in the service of the country—it was well known to all the members—but an Institution which could make the calls it had done

on such an active business man's time and find the ready response it had received was indeed fortunate. Sir Frederick's period of office would be memorable for the way in which he had placed the income of the Institution on a sure footing by his activities in enlisting the financial support of many of the great oil companies. Sir Charles Greenway, on vacating the office of President, threw out the suggestion of that financial assistance, and his colleague and successor had ably brought it to fruition. Through that support, and largely through the personal interest of Sir Frederick, the Institution had been enabled to secure its own offices and establish therein its library, as well as making satisfactory arrangements for dealing with the clerical and other work of the Institution. The Institution had to justify the financial help it received by doing all it possibly could for the advancement of oil technology. In that way only could it make some adequate return for the support it received and also an adequate return to Sir Frederick Black for his labours in achieving all that he had in the interests of the Institution.

Sir John Cadman, in seconding the vote of thanks to the retiring President, said that no one who had occupied the Presidential Chair of the Institution had filled the office better than Sir Frederick Black. On all occasions he had done what was required of a president to the honour and dignity of the Institution. He had had some very difficult questions to deal with and the Institution had come through his period of office in a very much stronger and healthier condition than when he entered it. The President had referred to the financial position of the Institution and the manner in which it had been improved during the year. It was entirely due to the late President's activity that the finances had been improved, and they were exceedingly grateful to him for it. He had great pleasure in seconding the resolution.

The resolution of thanks was carried by acclamation.

Sir Frederick Black, in reply, said he was almost overwhelmed by the kind things that had been said about him. The realization that he was qualified to fill the position of an Oklahoma driller stamped him, he thought, as a genuine petroleum technologist, which was one of the points upon which he had formerly been in doubt. He had tried to bring to the service of the Institution a certain amount of general knowledge of oil matters, and he hoped also a modest amount of business capacity, but now that he had got right down to the drill he felt that he was one of the genuine technical members. He took it also as a very high compliment that so much success had followed his carrying round of the bag. That was, however, an embarrassing sort of reputation to hold. He had recently attended a meeting at which the new

President was present, when the question came up of further help being obtained from the oil companies with regard to a particularly useful object. He was drawing a long face at the estimate of cost, when one of his colleagues on the Committee rather gave him away by pointing to him, indicating that he was the fit and proper person to take in hand the position of collector. If that was his reputation he supposed he must try to live up to it for worthy objects. He again most cordially thanked the members for the kind vote of thanks that had been passed to him.

The following paper was then read :—

The Education and Training of a Driller.

By Alan W. Davson, F.S.I., F.I.Ar.

Introduction.—With the rapid development of drilling both for water and oil throughout the world the demand for efficient drillers at present far outstrips the supply, and with the advance of British interests in this sphere the potential scope of the Englishman as a driller is daily receiving more attention.

The main, though not necessarily the sole demand, for British drillers must arise where British administrators and technologists are engaged in the fields. The demand will receive sympathetic treatment in this country from those concerned in meeting it, and will gather added strength from independent technologists, who by the nature of their work and the experience arising from it rally to its support.

These administrators and technologists will all, it is supposed, be numbered amongst the members of this body, and it would appear, therefore, that a section of the members of this Institution directly or indirectly control the demand for and supply of British drillers, and that the education and training of suitable men for the work will be a matter of direct concern to them.

Reference to the journals of the Institution shows that this is, in fact, the case; but, on the other hand, the term education when linked with the practical requirements of a driller is likely at first to be regarded in some quarters with little favour and some apprehension. Moreover, this term savours of schools and bookmen, whereas papers read before this Institution are generally concerned with the scientific application of problems of the industry arising out of the professional practice upon which particular members are engaged or in which they possess a contingent interest. But it is becoming more recognized every day that the problems of education and the problems of industry

cannot be disassociated, and that careful education, educational training and selection of individuals to and for the various grades of industry is fundamental to the efficiency of industry and the welfare of the individual.

The education and training of a British driller is an interesting aspect of this broad subject, and the choice of suitable men is only possible by applying the methods Mr. Dalton, quoting the words of Bacon, urges technologists to pursue in their work, namely, "Not merely to adhere to known methods but to discover new; to overcome, not an opponent in distress, but nature by labour, and, lastly, not to guess elegantly and plausibly but to know certainly and demonstrably."

THE ENGLISHMAN AS A DRILLER.—In the past the Englishman, with some exceptions, has not proved satisfactory as a driller. His failure is attributed to many causes. It is a favourite complaint—not only in relation to drillers—that the young Englishman of to-day will not "take his coat off." It is said that he does not possess the "muscle sense" that men born and bred round a drilling rig inherit and develop, and that training acquired in Technical Institutes and shops eliminates "hazard"—"hazard" and "muscle sense" being essential factors in obtaining "gait" or "motion" on the rig and being requisite in other departments of the work. The lack of natural facilities in this country for training prospective drillers is adduced as an additional cause.

The problem is further complicated by at least a tendency to two schools of thought in relation to the status and functions of a driller; one of which regards the driller as the future technologist, and leaves it to time, opportunity and the individual to determine which grade he shall reach; and the other which regards the driller in terms of definite grades of a definite trade. Since no definite source of supply of drillers is available this tendency to two schools of thought, together with the vagueness as to the characteristics required in a driller, has resulted by necessity and experience at the present time in the selection being based on the likelihood of the candidate possessing "temperament." The former school, and many adherents of the latter, demand technical qualifications in addition, whilst the remainder eschew "temperament" and technical knowledge in combination as of too infrequent occurrence to hope for. In reference to drillers generally many technologists deplore the ignorance of the past driller, which they affirm has resulted in the loss of valuable engineering and geological data which should have been reported in the boring log.

It does not seem fully realized that the "temperament" desired or the "ignorance" deplored is the resultant of a combination of character-

istics, and that character is largely moulded by elementary education, environment and association. This, however, is the crux of the whole problem.

The Englishman has a deeply rooted empirical inductive tendency. Both employer and employee are accustomed to the method of observational selection—the result of a short interview. The case of the British driller serves, however, to emphasize the speculative nature of this method. The applicant has little or no idea of the work he is going to undertake, the conditions of life or its possibilities. Should he fail he will have lost touch with his past connections. He is chosen when an adult to be trained for a job which to many of his competitors of other nationalities is almost instinctive. He is chosen for vague characteristics, backed by testimonials of his ability in completely different spheres of life. It should be borne in mind, however, that no amount of subsequent training or experience that companies or combines can offer can create the characteristics and qualifications required. Successful selection by such methods is therefore dependent on uncommon judgment or good fortune.

It is submitted, therefore, that it is not intrinsically the Englishman who has been at fault in the past, but his failure has been due to the fact that education and industry have been shut up in watertight compartments, and that facilities for proper education, educational training and selection in this country before passing to the field have been neglected through insufficient analysis of his status and functions, and insufficient analysis and definition of the terms education and training *as they affect the driller*. The foregoing method of selection would seem equally unsatisfactory from the employers' standpoint. If this speculative choice should fail the employer will have paid passage money and will have maintained the applicant during an apprenticeship for which he receives no return.

Status and Incentives offered to the Modern Driller.—The desideratum appears to be collaboration within the industry and between industry and education. An improvement in the design of a machine involves a "preliminary specification." Research design and experiment will be directed to eliminating vagueness from this specification and reducing it to standard terms which are capable of exact definition. The first step in collaboration between industry and education is to adopt a similar method, and to examine the whole problem with a view to compiling a "preliminary specification." This should comprise a definition of a "driller," the incentive the work can offer, and the characteristics and qualifications demanded, in order to enable the educationalist to assist in his selection.

What, then, is the status of the driller in the employ of the companies

or of the large combines of which the industry is comprised? He is a skilled operative—a specialist in the drilling branch of petroleum industry. The job of a driller is to put a hole down to the required depth by one of the standard methods in the minimum time consistent with proper care and economy while successfully overcoming the forces of nature which act in opposition to his efforts. As his experience increases so should his knowledge of formations and of how to utilize his plant. The more he concentrates on his work the more he must specialize.

What incentives can combines or companies offer to the driller? They offer him, according to his grade, high rates of pay and other rewards which from the material standpoint will undoubtedly attract men who have been accustomed to think in terms of a few hundred pounds per annum. While the combines can offer these terms to its drillers the industry opens to the driller—who gradually acquires a high degree of technical skill and develops administrative ability—the way to contract drilling and to independence or to the status which independence infers. This question of contract drilling as an incentive is specially raised here as it seems that if men can be so educated as, after training and experience, to undertake this work satisfactorily, the smaller companies and syndicates will be saved considerable expense in testing areas, and the individual will have a real outlet for ambitious effort.

But drillers in the past have perforce become assistant managers and managers. This will become rarer in the future. The characteristics and qualifications of a driller and of a field manager are largely incompatible, and their education and training therefore require entirely different treatment. The driller is a specialist and a worker. The efficiency of the field manager of the future will be gauged by his ability to combine administrative knowledge with theoretical engineering training and practical knowledge, not only of drilling but of all the various mechanical and civil engineering and technical problems which will daily come before him as the field develops. The criticism which this statement may provoke will be largely due to the fact that the qualifications and duties of the various grades in the industry have in the past been ill-defined or not defined at all.

In the future the suspicion and misunderstanding possible on this score must be eliminated, and it is only by closer relationship between education and industry that this can be brought about. By this means the characteristics and qualifications which the industry demands, and the rewards it can offer—not only to the driller—but to all grades of the industry, driller, technologist and financier alike, will be clearly defined; opportunities of becoming efficient in the particular grade

chosen will be facilitated, and an outlet to the legitimate ambitions arising from this choice afforded. But if closer touch between industry and education is to define more clearly the grades and to accentuate their differences, is there not a danger that suspicion and misunderstanding between the grades may increase rather than diminish? High pay, superannuation funds, bonuses, technical status, suitable living and working conditions will not alone make an efficient driller or promote an efficient industry. The characteristics and qualifications essential in a modern driller will certainly result in an increase in the division of employments (specialization); they will certainly emphasize the difference between the grades, but they will at the same time bring a full realization as to the points of agreement which exist. They will produce a co-partnership of intellects awakening in each individual a human understanding and "technical sympathy" with his fellow-worker on points of common interest.

THE RÔLE OF "TECHNICAL SYMPATHY" IN DRILLING.—"Technical Sympathy" in industry may, it is thought, be defined as the appreciation by each individual of the contingent problems arising out of his work and the respective contribution by each individual of each grade towards their solution. Elsewhere it might be brushed aside as idealistic, sentimental, or an academic idea, but before this Institution it is necessary to labour its value. Technical sympathy—the desire for a knowledge of contingent interests and contingent problems is its *raison d'être*. It is, in addition, the new force in modern industry. It is the only antidote to specialization, the missing link between industry and social life and between the various grades of modern industry. It is the key to team work, to status and functions, to the discipline resulting from knowledge and appreciation of efficiency and to the highest degree of efficiency in industry, whether for gain or service. The degree of success which an Institution, enterprise or individual will achieve will be measured by the degree to which this force—technical sympathy—can be generated and radiate to react in all directions. Thus, from an ideal standpoint and as between director and driller there must be in each connecting link a sufficient knowledge of the actual life of a driller and of the difficulties attending his work, otherwise the force of technical sympathy cannot radiate between them and the full measure of efficiency cannot be achieved. Likewise the driller must possess a knowledge of contingent problems sufficient to enable him to appreciate the difficulties of those who specialize in the geology, the chemistry, the engineering problems or in the administration of the field so that he may co-operate in providing the valuable data which comes within his ken. In creating a basic knowledge of technical sympathy lies the reply to those who protest the ignorance,

of the driller in the past. The knowledge implied cannot be obtained simply by being born and bred around a rig. It can only result from elementary education and training in elementary principles, which will in the long run more than compensate for the loss of practical experience, and also need not be overlooked during this period.

Technical sympathy is therefore a necessary characteristic, and it is quite easy to set down on paper a further string of terms and to state that they constitute characteristics and qualifications which a modern driller should possess. They might be, however, as useless, being much more detailed and much more subject to criticism, as the single word temperament unless they are each capable of exact definition. But as constituting part of a "preliminary specification" it may be permissible to indicate broadly some qualities which will, it is thought, assist educationalists in their selection. These may be briefly summarized as follows:—

Characteristics and Qualifications required in the Modern Driller.

1. That the driller must be derived from the worker stock.

2. That he must be physically fit and capable of considerable physical endurance.

3. That he should be possessed of a highly developed sense of touch and rhythm.

4. He should possess individuality and technical sympathy.

5. He should possess a general technical knowledge and an ability to record his impressions accurately.

Just as the specification is imperfect and preliminary, so must the methods of the educationalists and the machinery created by the industry be imperfect. But imperfect as they may be they will assist in two directions. It is an axiomatic condition of the selection of men for industry that the most successful are those who most desire the particular type of work. It is almost equally axiomatic that if a man will not "take his coat off" he is either in the wrong job or there is insufficient incentive. It is as difficult for a job to find the right man as it is for the man to find the right job. In the case of the driller advertisement will not tap him. Search amongst Technical Institutes is likely to fail because the success of the driller depends on characteristics rather than qualification, and the Technical Institutes are concerned more with technical matters than with characteristics. Thus selection is restricted and the educationalist with the "preliminary specification" to go by, is more likely to keep trace of the most

suitable characters even though they have passed from his hands, and to bring this form of employment to the notice of those to whom it will naturally appeal.

The second direction in which these temporary measures will assist is that by the machinery created the applicant will have a chance to further investigate his choice while the industry by careful observation will be enabled to determine more certainly his specific value.

Immediate Schemes for Training and Selection in Preparation or Proposed.

A Course for Drillers at Birmingham.—Instruction in drilling has for some years been given to students attending the Birmingham courses, and a curriculum for a course for drillers is now in preparation at Birmingham University, a fact which only recently came under the author's notice. It may be seen, therefore, that evolution of thought amongst those who have, in conjunction with their long experience of the industry, considered the possibilities of the early education and training of prospective drillers in this country has led to this practical result. Evolution of thought originating in a practical study of the effect of drilling operations for water on Englishmen as conducted for the E.E.F.—carefully weighed and revised in relation to the characteristics and qualifications required in a modern deep well driller and based on the premises of the industrial conditions as laid down in this paper has led to a similar suggestion.

This dispenses with the necessity of considering the feasibility of the principles on which such a suggestion is based. It serves, moreover, to direct attention to and bring under review an important innovation. While the principle involved in the establishment of such a course as that proposed at Birmingham, and of a school such as is about to be discussed by the author is the same, proposals emanating from different sources may possess points of similarity and of difference which it may be useful to discuss and may, in the course of discussion, arouse that interest in the subject which is so desirable.

A School of Drilling.—The provisional machinery proposed by the author is a School of Drilling in this country for adults of twenty-two to twenty-three years of age previous to their passing to the field. The objects of such a school would be:—

(*a*) In conjunction with education and on the lines previously indicated to make a preliminary selection of men likely to be suitable as drillers.

(*b*) To give the applicant some insight into a driller's life.

(*c*) To make him conversant with the principal types of plant and tools in use together with the details of joints, etc., their uses, advantages and disadvantages.

(*d*) To imbue certain fundamental principles and practices common to all rigs and drilling work.

(*e*) To point out and develop interest in contingent problems in connection with drilling operations.

(*f*) Carefully to observe characteristics and qualifications of the applicant in relation to the work upon which he is engaged throughout the whole period.

The method to achieve these objects would be :—

1. To make the school a summer school (in huts or under canvas) from May to October, and to conduct it on lines as far as possible similar to camp life on a commercial field.

2. Subject to No. 7 below to utilize light plants chiefly—of all the various types and not necessarily new—and to form a store of old scrap plant which could be turned to useful purpose to meet the exigencies of the work.

3. To have a small portable workshop such as the lorry workshops used by the Tank corps for the work required in No. 2.

4. To place the camp in a district where within the smallest radius surface geological formations vary to the maximum degree.

5. Subject to No. 4 to place the camp in a convenient position so that technologists may be able to visit it with the least effort.

6. To establish the fact that the success of the scheme would be proportionate to the support it receives from collective units and the individual interest of technologists, not only in respect to financial aid, but in the use of skilled drillers and by the information received as a result of personal visits.

7. To base the curriculum and the plant utilized on the investigations of a representative committee of technologists and skilled drillers.

8. Not to attempt within the limits of this training to make a driller suitable to undertake the work of any one company at the completion of the course, but to teach that drilling is an "Inexact Science" treated in an inexact way, and to promote initiative amongst the pupils so that with training and experience they may be able to undertake any work which comes into their hands.

9. To develop a knowledge of contingent problems by reports on the daily work executed, a method which has proved most practical and effective.

10. To develop the "group mind" by promoting a knowledge of the history of drilling in the past and of its aims and possibilities in the future.

By means of the "preliminary specification" and the temporary school suggested some degree of co-ordination within the industry and between industry and education will be established, but it is essential to make one further suggestion. If this temporary machinery is gradually to increase in value and afford information which will in time enable it to be replaced by permanent machinery of great efficiency, it must be followed up by scientific methods, and with this end in view the author believes that the aid of industrial psychology would be of infinite value.

Industrial Psychology as an Aid to Selection.—Characteristics are the chief factors in an efficient driller. Characteristics vary infinitely with working and living conditions. The importance of good housing and the choice of suitable companions with whom the driller is to lead his life of isolation are now generally recognized. The tour of duty merits consideration from the modern standpoint, namely, that to exceed a certain physical or mental fatigue varying in accordance with the nature and condition of the work is to decrease a man's efficiency. The study of the question of fatigue in its relation to the driller and the plant in use is also of vital importance. The early driller originated his own tools and plant of low mechanical efficiency resulted, requiring of the successful operator physical rather than mental qualities. The study of motion, of fatigue, of rhythm in relation to the characteristics and qualifications of individuals are all matters pertaining to industrial psychology. It is admitted that industrial psychology is comparatively a new development in this country, and that there is considerable prejudice against it from all quarters. But trained psychologists who were prepared to take up a driller's life and pass through the various grades and were given facilities, as their experience increased, to make a careful study of the varying circumstances and conditions on the different fields and in the different countries, would, after such experience, be invaluable to the industry. The information gained as to the human being with reference to plant would be of considerable value to manufacturers in endeavouring to improve their designs. The practical experience and the study of the driller in the field would determine the degree (if any) to which standard tests could be introduced into the school to detect the sense of touch and rhythm required

and technical qualifications, whilst the information gained would enable imperfections in the "preliminary specification" of a driller's characteristics to be eliminated and terms substituted which should be capable of exact definition.

The suggestion of a temporary school would involve a small capital outlay on plant, camp equipment, etc., and running expenses in respect of lease of land, salaries, etc., but these should not constitute an excessive figure, and if the units who are prepared to take these pupils on the completion of their course—a course the curriculum of which they themselves regulate through the representative committee—are ready to pay the cost of their maintenance during this period the suggestion would seem to be a reasonable financial proposition.

It is the purpose of these temporary measures to centre interest around the problem under discussion; by practical demonstration to show that the proposed methods of choice are more certain of success than the present methods; and by this means to establish the fact that if there is a demand for British drillers the creation of a source of supply on the lines suggested constitutes a fundamental part of the future machinery of the industry.

As this becomes recognized the support of collective units generally will be assured, and by this means it will be possible to build up, step by step, the permanent and more efficient machinery to meet the future needs of industry as times resume their normal.

Outline Scheme for Permanent Machinery for the Selection and Training of Drillers.

It is now necessary to examine briefly the nature of such permanent machinery as the author has in mind, firstly, because the temporary measures do not fully fulfil the objects for which the paper was written; and, secondly, because the erection of this machinery would have to be started as soon as the necessary support could be obtained, as though simple in its nature, it would take at least five years to get it into full running order.

As we have seen, the temporary measures fail in two respects; they do not assure that the applicant shall possess the basic knowledge of technical sympathy upon which so much stress is laid, and they offer no training equivalent to the inherent knowledge of those who have been born and bred around a drilling rig.

Junior Technical Schools as the Sources of Supply.—The first of these defects will be overcome if the Junior Technical School be recognized as the main source of supply. The school is a full-time school for boys of thirteen to sixteen, and it satisfies every requirement in the "Preliminary Specification." It is for the education of boys from

worker stock. It develops individuality, it instructs in fundamental principles and leaves it to the boy to gain his experience by practical experiment, making him search abroad for his solutions and thus creating a basis knowledge of contingent problems. The practical training it affords gives a general basis of technical knowledge, whilst the system of booking notes gives him some idea of how to record impressions. In addition the *esprit de corps* fostered by the organized games, combined with the whole tone of the school, react to make the pupil develop his fullest effort in every sphere, and this will make him a welcome unit in the after group life in the field.

There are forty to fifty of these schools concerned in engineering educational training in this country, and as economic conditions improve they will rapidly increase in number. If two or three suitable boys can be found from each of these schools each year, the main source of supply of future British drillers should be assured.

Training Course in Drilling.—Leaving the Junior Technical Schools at sixteen to seventeen, boys so chosen would pass to a training course for drillers, which is the remedy offered for the second defect in the temporary machinery. Here they would be joined by others who have been recommended by Educational Authorities as specially suitable, and, through the necessity to make money, the ignorance of their parents or other causes, have not had the advantages of the full-time education of the Junior Technical School.

This course would be conducted on similar lines to those of the temporary school, utilizing the whole of the organization built up by this school. The aim of the course would be similar to that of the school, but its main object would be to secure the initial interest of the youth in his life's work. The youth to whom this life appeals will, if his interest is fostered early, rapidly begin to "think in terms of drilling." Problems can be brought to his notice upon which success is dependent and which will excite his interest; for instance, in *Bulletin* 182 P.T. 57 Bureau of Mines, America, the following passage occurs: "Motion is the engine control applied by the driller in the raising and dropping of cable tools. A driller who understands motion has mastered his trade so far as the operation of drilling tools is concerned . . . many drillers contend that there is little to the mastery of motion with the wire line; as a rule such men owing to their long experience regulate motion automatically."

On light drilling rigs used in the training course it will be impossible to demonstrate "motion" to any great degree, but it will be possible to make the prospective driller think about it.

Again the *Bulletin* states "success in fishing primarily depends on tool running." The principles of tool running can be demonstrated on

light rigs, and the prospective driller can be imbued with the importance of these and other general principles so that, with the other characteristics and qualifications arising from careful educational training and selection, he will, with experience in the field, attain much more rapidly than is at present possible to automatic control of motion, efficient tool running and other principles fundamental to the work.

There is generally a tendency in selecting applicants for work to put the bright side before them. In this training course, however, there need not be any, and should not be any hesitation in emphasizing the hard and dirty nature of the work, and its drudgery, monotony and isolation, because the disadvantages will be outweighed in suitable men by the very real incentives the life offers to their material instincts; the game with Nature which will appeal to their spirit of adventure and the wealth of contingent problems involved in which they will possess the basic knowledge to develop interest.

From Training Course to Field.—But, as previously stated, the work of a driller is a grown man's work, usually conducted in a hot climate, and the prospective driller will not be required in this capacity till between twenty-two and twenty-three. From the time he leaves the Junior Technical School at sixteen to twenty-two he must earn his living. Herein lies a real difficulty for the industry, the difficulty of maintaining his interest during the intermediate period. This can only be done by ensuring him :—

1. Permanent employment during that period.
2. That that permanent employment is leading towards his objective.
3. Facilities to maintain and develop his interest and knowledge in his future work initiated in the training school together with a sufficient incentive to make it worth while for him to do so.

This will necessitate the institution of a permanent central advisory body, comprised of commercial interests, technologists, drillers, etc., who would control the destinies of the future driller from the time he enters the training course to the time he is accepted by the company or combine for work in the field.

This body would be responsible, firstly, for co-ordinating with all firms possessed of a direct or contingent interest in creating a source of supply of drillers with a view to finding these youths permanent employment during the intermediate period which would develop their general knowledge with a technical bias, and in which they would be granted facilities to attend practical courses in drilling once a year at the place and time stated and arranged by the central authorities.

The second duty of this central authority would be :—

1. To determine the demand for drillers.

2. To prepare and remodel as necessary the curriculum of the training course.

3. To prepare and establish suitable correspondence courses during the intermediate period leading up to the yearly practical course of three or four weeks' duration.

4. To institute practical courses at suitable centres under skilled supervision, to demonstrate the work of the correspondence courses and to develop and revive his knowledge of general principles by practical experience in the handling of the heavier rigs.

The author believes that by some such machinery as outlined here the permanent needs of the industry could be met and that a source of supply of suitable men could be assured who, with training and experience, would make drillers second to none, capable of meeting successfully any competition they might encounter and a real asset to any field upon which they were engaged.

DISCUSSION.

Professor Sir John Cadman, in opening the discussion, congratulated the author on bringing forward a very practical problem in such academic terms. There was a great deal of material in the paper which was worthy of careful consideration. It was, however, by no means an easy paper to discuss, and it was rendered the more difficult in that the paper was in the hands of the members only just before the meeting. The author had been good enough to indicate that an attempt had been made at Birmingham to provide for the instruction of the driller. Personally he was not prepared at the present stage to state the scheme which Birmingham proposed to adopt, for the simple reason that the matter was still under very serious consideration, and it was by no means an easy matter to give an outline in any detail at the present stage. He did not quite appreciate what the author meant by technical sympathy. He was dealing with the education of a driller, and the whole problem involved instilling technical and scientific principles into the minds of learners. At the outset suitable men of the right physique were required for the purpose. He had had considerable experience in dealing with young men and, although some of them might have an outward appearance of not being ready to take their coats off, he had never seen them fail to undertake the dirtiest and roughest class of work when under proper instruction or when it became necessary. Having selected men with suitable characteristics,

it was necessary to give them a knowledge of the strength of the materials, to teach them the manipulation of the plant and machinery, the preparation, sharpening and tempering of the tools they were going to use. Having done this, something further was required that no doctrine or teaching could give them, namely, experience, which could only be obtained through a channel which it was idle for him to indicate to the meeting. It was perfectly true that fundamental principles must be laid down upon which instruction had to be given. It was necessary to give a sound educational foundation to these men who were going to become drillers, and to prepare them to develop by experience into really sound practical drillers. It was a difficult problem which could not be dismissed in a few moments. In its widest aspect it was one of those problems in regard to which unfortunately the teacher rarely saw the results of his labours; that was left to the next generation. He desired at a later date, when the Birmingham scheme was more mature in so far as the drilling scheme was concerned, to go further into the matter with the Institution; all he could do at the present moment was to compliment the author on having brought forward in a very interesting and fascinating way proposals for the education of the driller which he was sure would be worthy of the consideration of everyone who had that responsibility on his shoulders.

Mr. Gordon Pitt said the general subject matter of the paper was of a nature that must be of such immense interest to petroleum technologists in general and to the prosperity of the industry that he had dared to step into the breach, as he had had a reasonable amount of experience of and contact with drillers. Sir John Cadman had done most valuable pioneer work in raising the question of the serious education of the driller and making a university matter of it. Amongst the many schemes which were impeded by the war he believed the Birmingham University scheme was one which suffered as badly as most. It had hardly got on to its feet at the time, and the opportunities for its development were very much limited during that period. The paper raised a number of most important problems that confronted the youngster who had an instinct for drilling, or thought he had, and did not quite know what was the best way to set about getting the necessary instruction, and also the much more serious problems which confronted either the oil company or probably its unfortunate field-manager in attempting to get hold of suitable drillers to work in the field. His own experience was that the companies were rather too ready to leave that selection entirely to the local manager. Frequently he had comparatively little opportunity for any great breadth of choice. He might be located in some out-of-the-way sort of place and be com-

pelled to use whatever drillers he could obtain, while the authoritative officials at the London office were placed in another difficulty themselves, inasmuch as they could not obtain drillers at all. All that emphasized the necessity for some sort of standardized method of training, the necessary result of which would be a recognized pool from which drillers with a certain degree of training could be drawn. He thought the author made one quite useful point in indicating that the driller should be kept to his drilling more or less. His own practical experience had been that the average driller, however competent, expert and successful he might be as a driller, was not usually the type of man who would make a good field-manager, and possibly it would be to the advantage of all concerned if that position were not held out to him as an incentive. The driller was, he thought, essentially, as the author put it, a skilled operative or artisan—it might be a very high grade of artisan—and he should be given every incentive to become as proficient in his own work as possible, and the most suitable raw material should be chosen and trained with that end in view. But the qualifications which made for a successful driller would not, he thought, in most cases make for success as a field-manager. The intermediary man, the actual drilling superintendent on the field, might well be selected from amongst men who, while they had the general qualifications for field management, had had at the same time a lengthy experience as drillers. Probably in a sufficient number of cases that happy combination could be found to provide the necessary number of drilling superintendents, whose work should always be quite clearly distinguished from that of the field-manager himself. Most British-controlled oil companies and the very large majority of English oilfield managers would prefer to employ British drillers, but down to the end of his own practical experience in the field—and the same conditions obtained largely at the present time—the supply practically did not exist. There were two reasons for that, the first being, as hinted by the author, that drilling was an occupation which did not appeal quite so much to the typical British temperament as it did to some others, the second and more obvious reason being that the average young Englishman of the class that might take up that kind of work at present really had no opportunity of doing so. That the method suggested by the author would very likely lead in that direction was extremely probable, and he thought the Institution and the industry were most indebted to him for bringing forward a really definite practical suggestion. Those who had suffered from the lack of drillers, or the inefficiency of the drillers obtainable, realized very deeply how essential it was that in the best interests of the industry the problem should be tackled, and any move that could be made by the Institution to encourage the

supply of suitably trained drillers was one that merited its closest attention. One thing, however, he thought should not be overlooked, namely, that the driller should be encouraged to become a driller and not to become all sorts of other things. He should be a complete driller; he required education and training to a certain extent in directions not necessarily involved in the actual handling of the tools, the making of the hole, the setting of the casing, and so on, which were his trade. That came under the head of the author's suggestion of technical sympathy. Personally he had seen very fine drilling operations conducted and most promising wells brought in and the whole thing go for nothing in a comparatively short time because of the lack of the quality that the author referred to as technical sympathy. The driller at the present day was frequently too much concerned with what he called footage, whether he was paid for it per foot or not. His great idea very often was to drill so many scores or even hundreds of feet per tour, and he did not care very much exactly what he got at the bottom of it. Of course he wanted to get oil, and sometimes he was paid a bonus for the amount of oil he obtained, which was a very good thing in a way; but he did not take sufficient interest in the actual methods by which he obtained it. He desired to give one illustration in that connection. He had on a number of occasions seen a couple of gangs of drillers working night and day who subordinated practically everything to the footage of casing set per tour, so that when the productive sands were actually reached and the oil began to flow, they had literally wrecked their machinery through over-forcing it, so that the well was absolutely lost after its first flow, because the engines could not run and the drum could not be brought into use, owing to the fact that they had been worked to the last gasp in order to get down to the sand. He quoted that as a single illustration in order to emphasize the enormous importance of the driller being sufficiently educated to know that he must not over-stress his own particular section of the work to the disadvantage of the final result at which he, in common with other people, was aiming.

Mr. Cunningham Craig said he was afraid the importance and the practical nature of the paper had not been properly appreciated. The author had given a highly concentrated dissertation upon the making of a driller, phrased in such beautiful language that he was afraid some of the members might have considered it academic. As a matter of fact, the author had made drillers; he was in charge of all the drilling operations in Palestine. In the last push through Palestine he had to make drillers out of very unpromising material; he had to teach them technical sympathy and team work; he had to work with bits of old scrap that would not fit together in any way; he had to use

about five different kinds of rigs; but in the end he was one of the teachers who had had the good fortune to see the effects of their work. Some of the drillers he had taught had been very successful since in drilling for oil. The subject with which the author had dealt could, with all due deference to previous speakers, hardly be appreciated by professors; it could only be appreciated by the people who had to sit day by day in the derrick and see how the work was being done—in many cases how the work was not being done, and how the tools and tempers, and a good many other things, perhaps even the well itself, were being lost. He had had a good deal of that experience himself. The subject could also be appreciated by the men who had had to sit week by week in London and receive the drilling reports, waiting for news of oil being struck. One week news would be received that the tools had been lost down the shaft; next week news would be received that the drillers were waiting for something; the next week's report would begin with the statement that the casing had collapsed, or something else; the next week's report stated that the drillers were waiting for new plant to be sent, probably a great distance. An enormous amount of drilling time was lost through accidents that were easily preventable, if the drillers only knew something about the strength of the materials being used, if they were real mechanics. The amount of time wasted in that way would hardly be believed except by those who saw drilling reports week by week. In his opinion it was not a question of teaching drilling. Teaching drilling was no doubt a very good thing, and an academic course was also a very good thing in its way. Students could be made to go through the motions of drilling, but the subject of the paper was the *making of drillers*, which was a different thing altogether—first of all by selecting them, re-selecting them at a later stage, teaching them what a driller ought to know, and making a scientific, efficient driller who knew all about the materials he used, who was possessed of the necessary information with regard to the strata that the drills went through, and who understood what was happening at the bottom of the hole. The oil companies in this country were so accustomed to bad drilling that some of them hardly knew what good drilling was. They had to depend largely on drillers from other countries, from the United States, Canada, Galicia and other places. In his opinion most of the best drillers in all those countries stayed at home. Some of the more energetic ones, who wished to see the world, left home; but there was, if anything, too much for the best drillers to do in their own countries. Marvellously efficient drilling work was done in America by American drillers under very difficult conditions; but when similar conditions were encountered in a number of countries that he could name a succession of fishing jobs resulted;

material and time were wasted, and the companies were so accustomed to it that they thought it quite natural that half the time in drilling a well should be wasted. They were content if the well was drilled in the end, after months of trouble. The subject was a most important one, because, after all, oil was a British industry and would become more and more a British industry in the future. It was therefore most desirable that this country should not be dependent upon other countries, at any rate to the extent it was at the present time. There was a certain number of people who could teach drilling and make drillers in this country. In that respect the Institution could do something practical in connection with the formation of a school, beginning in quite a small way on the lines laid down by the author, so that the first real generation of British oil drillers might be commenced. They in their turn would teach others, and very soon, in the course of ten or twenty years, all the British drillers that were required would be obtained—highly trained, intelligent men possessing the technical sympathy which the author regarded as so important, and in regard to which he (Mr. Cunningham Craig) entirely agreed with him. If, however, the country went on as it was going on at present the oil industry would never be a really British industry. It was time to begin to endeavour to bring about that desirable state of affairs.

Mr. Hudson Hobden said he had listened with very great interest indeed, not only to the paper, but to the discussion, for the simple reason that both very greatly appealed to him personally, as he was a practical man. Fortunately for himself, his experience had been gained in the mid-continental parts of America, where bad drilling was not understood. The drillers in that part of the world were men who had lived their lives in the oil-fields and had graduated to become drillers. Some started as roustabouts, then took to dressing tools and eventually from being tool dressers they became drillers. There could be no doubt about it that, in educating a driller, a difficult problem had to be attacked. He had known splendid tool dressers who could not run a string of tools. On the other hand, he had come in contact with men who had worked at dressing tools for a few months and then had taken over the tools and become successful drillers. It was purely a matter of temperament, of a man being suited for that particular kind of life. The intricate practical knowledge that a driller required was very hard to teach; he must gain it for himself. The working of the tools and everything else was something quite different from anything that existed in any other industry; and he challenged the members to name any institution in the world, any University or any College, which aimed at being able to give a driller practical experience. His university was the field. He desired to tell the members of a scheme that

had been carried out, and was still being carried out, in America by one of the largest producing companies there for the training of drillers. After he had stated what that company was doing it would give people interested in oil in this country food for thought, for the carrying out over here of what he considered to be a beautiful idea. In 1919 he was put in charge of the Empire Gas and Fuel Company's operations in the State of Kansas. At that time they were the largest independent producers in the mid-continental field. They practically controlled the entire El Dorado field right away through, and also the Augusta field. He was called to Oklahoma to attend a Conference at which a letter was read from Mr. Henry Doherty, of New York, in which he suggested that the Chief of the Engineering Department should visit all the engineering colleges throughout the States and pick out men who were anxious, after finishing their course in college, to enter the oil business. Mr. Doherty offered in his letter to recruit the men, and if the Conference considered his scheme a practical one, for those men to join the Company, and first of all be put through the office routine, in order that they might learn the office side of the work before they entered the field. Afterwards they were to be sent out into the field, and there study the practical side of the industry. Each one of the engineering students in question was of an entirely different stamp from the men who were generally found round the rig; they were educated men, and willing to learn all they could. As a result the scheme was adopted, and wherever the Company was running what were termed "Company tools" one of the engineering students was attached as a cadet on the job. He practically became an assistant to the tool dresser, and eventually became a tool dresser himself. In those cases where it was found the man had an instinct for being able to run tools he did so, but the main object of the education was to make production men. He was happy to be able to say the scheme was working very successfully. The men entered into the work with wonderful spirit, and, at the time he left the Empire Gas and Fuel Company last year, it had a little over three hundred cadets, recruited from the various colleges throughout America.

There was one other point to which he wished to refer. For a number of years the system of drilling remained practically unchanged. A little while ago he saw a picture of the first rig constructed in Pennsylvania and it was constructed on the same principle as the standard rig as used to-day. There were only two systems known in America—standard cable tools and rotary. But at the present time science was entering the oil-fields. The Empire Gas and Fuel Company, during his connection with it, drilled in the El Dorado field the first well drilled with electric power. The old drillers said that it was impossible to

utilize electric power for drilling. They had been given the lie, and as a matter of fact the entire field at the present day was being operated with electricity. Wherever it was possible to get electric power it was found that the big problem connected with water and fuel had been solved. Very few men liked to work round a rig in which the fuel used was coal; they preferred oil; but they were now being educated to the fact that electricity was much better. That would all tend to prove that the oil industry, from a practical standpoint, was making rapid strides, and making many improvements upon the old ideas of drilling wells.

The President said he was sure the members would agree that they had listened to a very interesting discussion, and that he would be expressing their feelings in saying how much they had enjoyed it, particularly Mr. Hudson Hobden's contribution.

Mr. A. W. Davson, in reply, said he had been extremely interested in Mr. Hudson Hobden's remarks because they had been made by a man who was right in the thick of the work and knew what he was talking about. Mr. Cunningham Craig had been kind enough to say that he (the author) knew something about the subject, but in comparison with Mr. Hudson Hobden his practical knowledge was insignificant. When he was in Sinai he was called upon to start a Boring Section and had thirty Englishmen allotted to him for this purpose. After six months of trial and error work, Captain Mangin took charge of operations, and in a previous paper, before this Institution, the work executed by the Section is recorded by him. Remaining with the Section, the author had the opportunity for two years of studying the effect of light drilling work on Englishmen. The thirty men to whom he had referred came from all parts of the British Isles, and under the Army conditions under which they were working, they were up against some of the greatest mental opposition that it was possible to imagine. The conditions were rendered more difficult by the fact that about five different types of rig were in use.

He often used to find that someone, who knew nothing about the work at all, had come along and entirely upset the psychology of the men, and that the progress of drilling had suffered in consequence. That was where he obtained his ideas as to conditions under which men either could be expected to work efficiently or not, and thrown into touch with men of all branches of the oil industry on his return to civil life he found an almost uncanny parallel between incidents which determined the efficiency of the driller on the oil-field and incidents which determined the efficiency of the operator for the purpose then in view. If there was sufficient sympathy between the control and its various grades and the driller—not ordinary sympathy as to whether a

man was well or ill, but sympathy expressed in a sufficient *knowledge of the nature of work and its difficulties*—that work would be accomplished. He was unable to speak in regard to the qualities of the American, but he was certain, after the experience narrated, that unless that sympathy existed, good work would not be done by Englishmen. Mr. Hudson Hobden had made the statement that Science was now coming into its own in connection with the drilling industry. In his opinion the more Science entered into the drilling industry, the less would temperament, which was only a vague characteristic, count. As he said in the paper, if a few young industrial psychologists were prepared to undertake this work, and as their experienced increased were afforded facilities to study the varying circumstances and conditions in the different countries, it would be possible gradually to discover what the so-called temperament was, and by this means the mystery surrounding the characteristics and qualifications required in a modern driller would be cleared up.

Mr. Hudson Hobden was at one with him in that in showing by his illustration that very careful selection and training of prospective drillers was undertaken by the firm to which he referred. As to whether any form of practical training could be of practical value away from the field, it must, the speaker thought, depend upon the particular purpose of this training and the particular problem which it was intended to solve. If, as Mr. Hobden said, the work was becoming more scientific, it would only serve to make training and selection more possible at a distance from the job, because the work would be less inexact and the characteristics and qualifications of individuals required for it more definite. In this country where drilling did not constitute an industry, and where fields were not adjacent to training facilities, the author submitted that it was essential firstly to determine and get hold of the type of young man required; secondly, to give him a slight insight into the type of life and the work he was going to undertake; and, thirdly, by means of the first two suggestions to eliminate to a large extent men who would never make drillers, and so to reduce the outlay in sending men abroad and training them without getting from them any adequate return. That was the basis of his paper. He had not suggested anywhere in the paper that it was possible to do without training and experience. Training and experience were the only things that would make a driller, but it was necessary to obtain the right type of person first. It was very gratifying to him to learn that the views of Mr. McMullen, who had actually done deep drilling work, coincided very much with those of his own. The remainder of his reply he would communicate in writing to the Institution.

The President said it was hardly necessary for him to move a

formal vote of thanks to the author for his very interesting paper, in view of the enthusiasm it had evoked.

It afforded him much pleasure to announce that an extra meeting of the Institution would be held on Wednesday, April 27th, when the Council had been fortunate enough to arrange for Dr. T. O. Bosworth to deliver a lecture on the Mackenzie Oil-fields of Northern Canada. Dr. Bosworth, who was a member of the Institution and formerly in the British Geological Survey, was the leader of the original expedition which resulted in the location of the Mackenzie territory as an oil zone, and the Council were particularly gratified at the opportunity of arranging a lecture by so distinguished a man, who, while on a short visit to this country, had very kindly offered to give the Institution the benefit of his experience in connection with the important oil-field which was being developed in the north-west of Canada.

The meeting then terminated.

Contribution from Mr. GEORGE HOWELL.

No one but a petroleum technologist could appreciate the paper presented by Mr. Davson to-night at its true value. The training of a driller constitutes one of the most important duties to be undertaken by the heads of the profession, and there is no surer school than the field. In this respect Galicia's example might be profitably copied. The grading of men and the awarding of certificates of efficiency, as in the Merchant Service, is not only a thorough and excellent way of making good drillers, but the method of procedure is a stimulus to men desiring to become first-class users of a string of tools. There was no doubt that the University of Birmingham, through Sir John Cadman's efforts, is destined to become a power in solving the problem of the best course to be taken in educating a driller. Still, practical experience in a real oil-field should be compulsory before certificates recording the higher grades are awarded.

In the Toyah (Texas) oil district, the State is considering legislation compelling all oil-well drillers to undergo a rigid examination, in other words, to pass legislation that the qualifications of drillers shall be known by virtue of certificate and authority. As regards British drillers, this Institution could well afford to be not only the adjudicator but the grantor of certificates; and these certificates should mark the man. In Galicia it was the practice that a man, unless he held a first-class certificate, was not allowed even under a manager to take full charge of a drilling operation. The idea of the Texas Authorities is that only when a driller can offer evidence of efficiency shall a licence to practise his profession be given. In the development of this idea a law

would then be enacted that the hiring of incompetent drillers by contractors and companies or independent well owners would be an offence punishable by a fine or other suitable penalty.

Much irritation and serious loss of large sums have been the result of employing incompetent drillers. Many a hole put down almost to completion stage has been ruined; many important signs and indications of oil horizons have been ruthlessly passed and hidden oil-beds have for years been lying undiscovered between the surface and the lower strata where the bit has penetrated. This has been already demonstrated in certain fields in America, where to-day, the result of re-examination of the strata, intermediate oil-containing strata have been discovered and in one instance a 1000-barrel well brought in. It is easily realizable that inexperienced drillers can easily pass important oil sands, as well as be responsible for large losses to the petroleum industry. Efforts in training a driller should be made to instruct a driller-elect *inter alia* in the knowledge of the manner of correctly recording various drilling stages; and also important is the handling of water intrusion and casing troubles.

As the ultimate success of an oil-field depends on good drilling, I congratulate Mr. Davson most heartily on adding to the records of the Institution a paper not only of academic interest but full of practical suggestions. Recognized status of a driller is called for and incentives in the shape of graded certificates would, I think, help to create the status.

Unquestionably technical sympathy does play a very important part in drilling efficiency; while psychological treatment is, as it has been proved in other industries, of great value, and the study of modified psychology might well form part of a driller's education.

The Fifty-sixth General Meeting of the Institution was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C., on Wednesday evening, April 27th, 1921, Professor J. S. S. Brame, the President, occupying the Chair.

The President, at the opening of the meeting, said that it was unnecessary for him to introduce the author of the paper, Dr. T. O. Bosworth, to those who had any knowledge at all of petroleum geology. He was an old member of the Institution, and although he had not read a paper before it he had contributed to the discussion on the valuable paper which Mr. Cunningham Craig read in 1915 on the Prospective Oil-fields of Western Canada. In proposing a vote of thanks at the end of that meeting, the then President, the late Sir

Boverton Redwood, extended to Dr. Bosworth an invitation to read a paper to the Institution on the Northern Regions of Canada. That was in 1915, so that a long interval had elapsed between the invitation and its acceptance. The interval, however, had been spent very largely in further exploration work in the northern regions of Canada, which would add very appreciably to the value of the paper. That exploration work had, in the main, been carried out under the author's direction, and he thought the Institution was to be congratulated on its good fortune in having a paper from him during a comparatively brief visit to this country.

He had received a letter from Sir John Cadman, a Past President, regretting that he had been called away to the north of England, as otherwise he would have liked to have been present and join in the discussion.

The following paper was then read :—

The Mackenzie Oil-field of Northern Canada.

By T. O. Bosworth, D.Sc., M.A., F.G.S., F.R.G.S.

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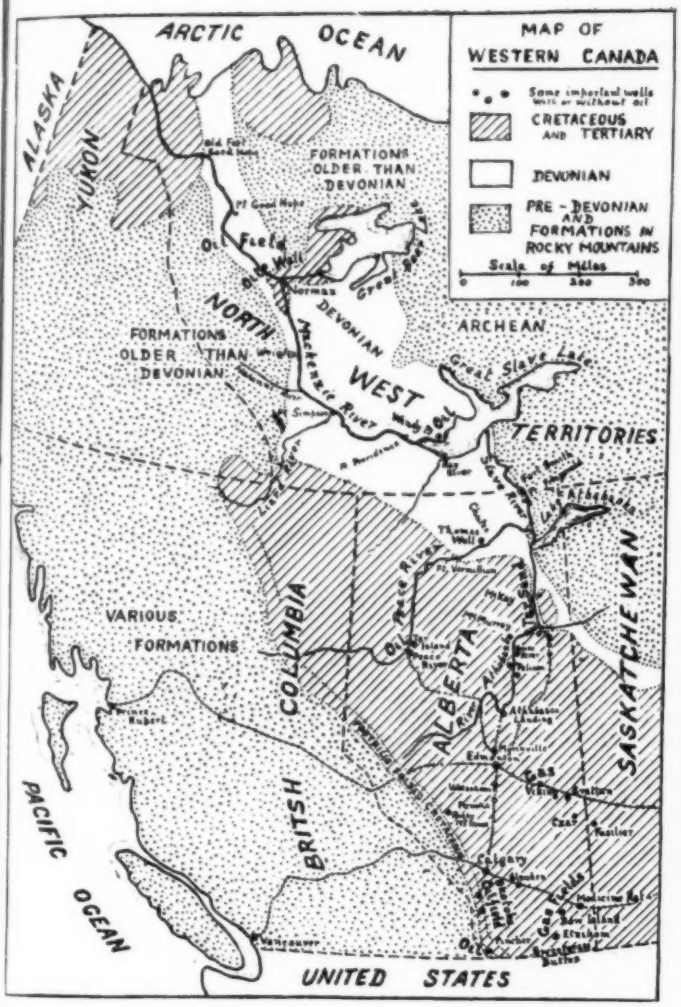
I. Introduction.

Some years ago I had the privilege of saying a few words before this Institution about the prospective oil-fields, which had been outlined in Northern Canada during my geological exploration in 1914.

The Mackenzie Oil-field, which is now the subject of so much attention, was the most northern of those fields, and the flowing well which was recently "brought in," is the No. 1 test well which we located there seven years ago.


MAP OF
WESTERN CANADA
Some timberland wells with or without oil
CRETACEOUS AND TERTIARY
DEVONIAN
PRE-DEVONIAN AND FORMATIONS IN ROCKY MOUNTAINS
Scale of Miles
0 100 200 300
ARCTIC OCEAN
ALASKA
YUKON
FORMATIONS OLDER THAN DEVONIAN
Old Fort Good Hope
Ft Good Hope
Oil Field
Oil Wells
Norman
Great Bear L.
DEVONIAN
NORTH WEST TERRITORIES
ARCHEAN
Great Slave Lake
Mackenzie River
Simpson
Hay River
Fort Providence
Fort Resolution
Fort Smith
Athabasca
Lesser Slave Lake
Peace River
Peace River Landing
Dunvegan
Fort Vermilion
Waterways
Athabasca Landing
Edmonton
Battleford
Prince Albert
Regina
Moose Jaw
Calgary
Medicine Hat
Lethbridge
Coal Fields
Banff
Field
Revelstoke
Kamloops
Ashcroft
Yale
Vancouver
Victoria
Nelson
Fernie
Crow's Nest Pass
Prince Rupert
VARIOUS FORMATIONS
COLUMBIA
ALBERTA
SASKATCHEWAN
BRITISH
PACIFIC OCEAN
UNITED STATES

General Map.

GEOLOGICAL MAP
MACKENZIE OILFIELD
T.O. Bosworth
1914
Scale of Miles.
0 5 10 15 20
BEAVERTAIL ANTICLINE
BAT HILLS ANTICLINE
EAST MOUNTAIN ANTICLINE
Caribou Mt.
WOLVERINE ANTICLINE
Limestone Mountains
Fort Norman
Tertiary
Cretaceous
Camp Creek Series
Fort Creek Shales
Beaver Tail Limestone
Rampart Limestone
Hare River Shales
Bear Mt. Series
Barren Limestone
N

This "Discovery Oilwell" is situated on the right bank of the Mackenzie River, some 45 miles beyond the little trading post known as Fort Norman, and within about 90 miles of the Arctic Circle. It is the first well drilled in the North-West Territory, and the most northern oil-well in the world.

II. Transportation to the Oil-field.

From Edmonton, the nearest large town, the distance to the oil-field is about 950 miles north-westward, in a straight line.

Almost immediately north of this city begins the great forest of spruce and poplar—one of the largest forests in the world—extending to the Arctic Ocean, and covering half the North American continent.

Three hundred miles beyond Edmonton the roads and railways terminate, and travel is almost entirely restricted to the great lanes through the forest which the rivers provide.

These rivers—the Athabasca and the Peace—unite to form the Mackenzie River, which flows northward to the Arctic Ocean.

The Old Route.—At the time of my journey in 1914, the trip to the north was much more difficult than it is to-day.

The railroads then went no further north than Athabasca Landing, and the first 220 miles of the waterway, as far as Fort McMurray, was traversed on scows.

Owing to the 80 miles of difficult and dangerous rapids, much handling of the freight was necessary; and each year some lives and some of the goods were lost.

On the return southward it was necessary to "track" up-stream, pulling the scow by ropes, an arduous task (which occupied my party three weeks).

The other 1150 miles of the journey was comparatively easy. It was the difficulties of this first 220 miles that so long retarded the opening up of the north country. Few made the trip, except the trappers, traders and missionaries.

Transportation now Greatly Improved.—But all this has been changed during the past few years, by the construction of two new railroads, which eliminate the hard trip down the Athabasca. Passengers and freight are now conveyed by rail to the steamboats beyond McMurray.

Thus the railroads and the oil-field are now connected by 1100 miles of navigable waterway, interrupted only at one place for a length of 18 miles.

This main route from Edmonton to Fort Norman, may be summarized as follows:—

By Rail—	*Athabasca River Route.*	
Edmonton to McMurray		300 miles
By Steamer—		
Down Athabasca River to Lake Athabasca		160 ,,
Across west end of Lake Athabasca		20 ,,
Down Slave River to Fort Fitzgerald		90 ,,
By Road—		
Across Portage to Fort Smith		18 ,,
By Steamer—		
Down Slave River from Fort Smith to Great Slave Lake		175 ,,
Across west end of Great Slave Lake		90 ,,
Down Mackenzie River to Fort Norman		517 ,,
	Total	1370 miles

An alternative route (only partially different), by way of Peace River, also is being much used, because, although it necessitates two portages instead of one, it has, at present, a better railroad connection than the Athabasca route.

By Rail—	*Peace River Route.*	
Edmonton to Peace River		300 miles
By Steamer—		
On Peace River to Fort Vermilion Chutes		330 ,,
By Road—		
Across Portage at the Chutes		2 ,,
By Steamer—		
On Peace River from Chutes to Slave River		195 ,,
On Slave River to Fort Fitzgerald		68 ,,
By Road—		
Across Portage to Fort Smith		18 ,,
By Steamer—		
On Slave River from Fort Smith to Great Slave Lake		175 ,,
Across west end of Great Slave Lake		90 ,,
On Mackenzie River to Fort Norman		517 ,,
	Total	1695 miles

Certain variations of the above routes, and some short cuts also, are possible to the man without baggage, who is accustomed to northern travel.

The "Open Water" Season.—It is only during the summer months that these northern rivers are open.

On both the Athabasca and the Peace the ice goes at the end of April; and on the Mackenzie it breaks up in the latter part of May. It is the ice on the Great Slave Lake which delays the transportation, for this generally remains until the middle of June.

The Mackenzie River remains open for navigation for about four and a half months; but during October the winter is advancing from the north, and those who do not wish to stay, must hasten southward to avoid being frozen in.

These great rivers are much alike in character—all being wide and shallow. At low stages of the water their channels are not to be depended on for boats of more than six feet draught.

The current ranges from about four miles an hour, to two miles an hour, as we go from south to north.

The lakes are subject to bad storms, and it is sometimes rough on the Mackenzie River, which has a width of from one to three miles.

A number of steamboats, built in the north, ply upon these waterways. Most of them are flat-bottomed stern-wheelers, of 4–5 feet draught. The largest is the s.s. *D. A. Thomas*, on the Peace, which has a length of 175 feet, and a carrying capacity of 300 passengers and 200 tons of freight.

On the Mackenzie River there are similar steamboats of about 150 tons register. Many smaller boats of other types also, are in use.

During the summer months the weather is hot, the vegetation is luxuriant, and the mosquitoes are very severe. Game is scarce, but in some parts of the lakes there are abundant fish.

Few inhabitants are seen, except at the trading posts, which are small villages situated along the route, at intervals of one or two hundred miles. The residents are chiefly Indians and half-breeds, and generally a trader or two and a missionary, and sometimes one of the R.N.W.M. Police.

The traders do not wish to part with any of their stock of supplies except in exchange for fur. Formerly money was not in use, but it is now gradually being introduced.

Winter.—The winter temperatures in the north do not go much lower than those experienced in the worst part of winter at Edmonton

or Winnipeg—but they continue much longer. "Forty below" weather may last for six weeks or more.

Though this may necessitate the shutting down of field operations for two months or so, it certainly will not prevent Canadians from developing these northern fields.

Transportation by Air.—Several "all-steel" aeroplanes are being employed this year to go to and fro between Edmonton and the oil-field.

It is said that they can make the trip with passengers to Fort Norman in thirty-six hours.

In March they made a successful trial journey to the Great Slave Lake, and back, after which they departed for Fort Norman. It is reported that dirigibles also are to be utilized.

III. Problem of Transporting the Oil.

Transportation by Oil Barges at Present.—Until the oil-field is further proven and developed, the oil will be brought southwards along the waterway, to the railroads of Alberta, by the route which already has been described.

For this purpose, motor barges of several hundred tons capacity can be employed. Two fleets of these vessels will be required—one operating north of the Smith portage, and the other south of it.

The journey for the oil, consists of three parts:—

(1) Oilfield to Fort Smith.

From the wells, the oil will be conveyed up the Mackenzie River, across the end of Great Slave Lake, and then up the Slave River as far as Fort Smith. This voyage of about 800 miles will be performed by the first fleet of barges.

(2) Fort Smith to Fort Fitzgerald.

At Fort Smith, where navigation is interrupted by the Smith Rapids, the oil will be pumped across the rapids, through an 18-mile pipeline, into the second fleet of barges, which will be awaiting it at Fort Fitzgerald.

(3) Fort Fitzgerald to Fort McMurray.

From Fort Fitzgerald the oil will be conveyed along the upper portion of the Slave River, across the end of Lake Athabasca and up the Athabasca River as far as Fort McMurray, where tank cars on the railroad will receive it. This voyage of 270 miles will be performed by the second fleet of barges.

A 200 ft. cliff of Fort Creek Shales, up one of the tributary streams which flow into the Mackenzie River from the Limestone Mountain Range. It was in these highly bituminous black shales that the large flow of oil was struck by the Discovery Well.

The Discovery Well, before the oil was struck.

Further railroad construction, and improvement of the waterways also, are certain to be undertaken if the developments in the oil-field justify them.

Extension of the present railroads to Fort Smith or to Hay River, which has long been projected, would greatly simplify the transportation scheme.

Possibly the oil will be partially refined in the north, to reduce the costs of transportation.

Pipeline Eventually.—If the oil-field fulfils present hopes and expectations, the transportation of the oil doubtless will in due course be accomplished by pipeline; and already several schemes are under consideration for piping the oil to one of the inlets on the Pacific coast. The shortest distance to tidewater is 550 miles. Such a pipeline would not be long in comparison with some of those already operating in the United States, but owing to the wild country to be traversed, the cost is estimated in millions of dollars.

IV. Stratigraphy.

The strata exposed in the Mackenzie Oil-field district include:—

Tertiary . . .	Shales, sandstones, and lignite.
Cretaceous . .	Clay-shales and sandstones.
Devonian . . .	Limestones, shales, and sandstones.
Silurian . . .	Limestones, etc.

It is in the Devonian only that the oil and gas have been found.

Devonian strata extend over much of Western Canada, but are largely covered over by the Cretaceous deposits.

In Northern Alberta the Cretaceous cover has been cut through by the Athabasca River and the Peace River, exposing these Devonian rocks.

Further northward, the Devonian has been more extensively uncovered by denudation, so that it now occupies the surface throughout a large, long region, reaching right across the North-West Territory, along the Mackenzie Valley to the Arctic Coast.

The approximate boundaries of this northern area of Devonian rocks were mapped by R. G. McConnell, of the Canadian Geological Survey, during his exploration in 1887; and many observations are recorded in his report. But previous to my investigation of 1914, no attempt had been made to subdivide the Devonian of this region into its constituent members, nor to elucidate the structure.

In the present paper we are concerned only with the lower part of the Mackenzie River, from Fort Norman northward.

The Discovery Well, before the oil was struck.

In this region I divided the Devonian provisionally, into the following main groups:—

Member.	Character.	Thickness.
Camp Creek Series.	Clay-shales and sandstones. Greenish and vari-coloured. Marine shells and plant particles.	2000+
Fort Creek Shales.	Bituminous shales with thin seams of sandy limestone. Black, but in places burnt brick-red. Plants and marine shells.	500–1000
Beavertail Limestone.	Bituminous limestone beds. Black or dark. Corralites and other marine fossils.	350
Rampart Limestone.	Massive grey limestone. Many fossils, marine.	100–200
Hare River Shales.	Calcareous clay-shale. Grey-green. Few fossils, marine.	300
Barren Series.	Brecciated dolomite and white, grey, and buff limestones, without fossils.	2000 (?)

The petroliferous character of these formations will be further mentioned after the geological structures have been discussed. A more detailed account of the deposits and their fossils is being published elsewhere.*

V. General Structure of the Devonian in North-Western Canada, as observed on the Journey North.

The Devonian formations are spread over a large part of Western Canada. But about three-quarters of their area is thickly overlain by the Cretaceous.

The eastern margin of the sheet of Devonian rocks crops out in the Palæozoic escarpment of Manitoba. The line of it passes northward by Lake Winnipeg, Lake Athabasca, Great Slave Lake and Great Bear Lake, to the Arctic coast.

On the west side of the Devonian area, the beds are upfolded in the Rocky Mountains.

* Report by E. M. Kindle and T. O. Bosworth, for the Canadian Geological Survey

Between their escarpment on the east and their folds on the west, the Devonian strata are thought to be more or less continuous and undisturbed.

Thus in Southern Alberta and Southern Saskatchewan, the great sheet of Devonian strata, underlying the Cretaceous, is believed to be practically horizontal.

In Northern Alberta, as we travel northward down the Athabasca or the Peace, where the Devonian is here and there exposed to view, we see that here too, the limestones have a general horizontal attitude, though they also show many small gentle undulations.

Further northward, in the North-West Territory, the same general horizontality is observed in the scanty exposures around the western end of Great Slave Lake.

Continuing on the Mackenzie River, the first 250 miles of the valley, from Great Slave Lake to the mouth of the Nahanni, apparently are occupied by horizontal Devonian rocks. In this part of its course, the river flows W.N.W. between low banks, in which only a few small exposures of greenish shales are seen.

There seems to have been a general idea that this horizontal attitude of the Devonian was maintained throughout all the Mackenzie Valley. This, however, is far from being the case.

At Nahanni River, about half-way between Fort Simpson and Fort Wrigley, the river had closely approached the Mackenzie Mountain range, and is sharply deflected northwards. At this place folded rocks, of which part presumably are Devonian, are visible from the river in Mount Camsell and other hills.

Proceeding northward a further 70 miles down the river, to Fort Wrigley, the Mackenzie Mountains recede from view on the west side, whilst on the east side we see, and soon approach, the Franklin range.

At Fort Wrigley, Rock-by-the-River-Side, etc., the river is in contact with outlying parts of these mountains; and here again, folded Devonian rocks are visible.

From Fort Wrigley to Fort Norman, the river proceeds on a N.N.W. course for some 130 miles, gradually drawing out of sight of the Franklin range.

After passing Fort Norman, the river comes in contact with another mountain system—referred to here as the Limestone Mountains.

These mountains, which consist of anticlinal folds of Devonian rocks, are encountered by the river for a distance of a hundred miles.

It is in this territory that the favourable indications and structural conditions were found, which have led to the recent strike of oil. This is the site of the new oil-field.

Beyond the Limestone Mountains, the river passes on to the Ramparts, and through them to Fort Good Hope. Here, and for more than 100 miles beyond, the Devonian is much exposed, but the beds lie horizontally, and within sight of the river, no further folding is discerned.

VI. Structure in the Mackenzie Oil-field.

A few miles beyond Fort Norman, the Mackenzie turns sharply to north-westward, so as to flow along the S.W. flank of the Limestone Mountain range.

This straight course, known as the Long Reach, is maintained for 75 miles, parallel with the range, and a few miles from it. The river then turns northward, and in a distance of 25 miles it cuts across the trend of the mountains, at their western end.

The Devonian strata of the Limestone Mountain district have been thrown into a series of bold asymmetrical folds, whose axes plunge up and down, steeply and frequently.

In the synclines, the soft Camp Creek series and Fort Creek shales give rise to low ground. But wherever the upward pitchings of the anticlinal axes bring the arches of the Beavertail limestone up above the general level of the land, the denudation has developed out the arches, as conspicuous anticlinal hills.

Four main anticlines are thus revealed where the Mackenzie River crosses the folds. At this place all of them are pitching down towards the west. In order from south to north, they have been named (by the author*) :—

Wolverine Anticline.
East Mountain Anticline.
Bat Hills Anticline.
Beavertail Anticline.

The four axes lie roughly parallel, at intervals of about seven miles. Their direction, where the river crosses them, is slightly north of east; but on the east side of the river they bend round to a E.S.E. course, which is perhaps their more important direction.

These four main anticlines are very much alike, each forming a line of more or less discontinuous limestone hills, exceeding 1000 feet in height.

* Anticlinal structure in the region was first observed at Bear Mountain by R. G. McConnell, but the main folds were found and mapped (by the author) n 1914.

Photo by Dr. Bosworth.

A limestone arch on the East Mountain Anticline. The axis pitches down towards the observer.

The Wolverine Anticline, exposed in the river banks at Carcajou Mountain. The axis trends along the cliff; and the crest of the arch of Beavertail Limestone is about three-quarters of the way up. The steeply inclined bed of limestone, which forms the face of the

In each of these anticlinal ranges a core of the grey barren limestones, or of the Rampart limestones, is laid bare in the parts where the axis rises to its maximum height.

On each of them the bituminous Beavertail limestone forms steep dip-slopes; and generally it is also seen forming conspicuous arches on some parts of the crests.

Low down on the flanks, the Fort Creek shales are found, followed by the soft Camp Creek beds.

Near the axes, the strata at the core are very steeply inclined; but a mile or two away, on the flanks of the anticlines, the dip is 15°–35°.

Wolverine Anticline.—Of these four anticlines, the southernmost was the most studied. It is finely exposed in the river cliffs at Carcajou Mountain, a hill mass on the right bank of the river, 1000 feet in height. Here for a distance of fifteen miles the axis of the anticline trends along the river cliff, and the core is well exposed. This part of the fold is very steep, and its south flank is seen as an almost vertical wall of Beavertail limestone, which has controlled the course of the stream and now forms its cliff for about ten miles. The north flank, which has a gentler dip, forms the inland-facing slope of the hill. The fold pitches steeply westward, and towards the west end of the cliff the arch of limestone passes underground. Traced eastward this anticlinal ridge turns to a S.S.E. direction, and appears to be continuous for seventy-five miles parallel with the Long Reach.

The axis lies seven or eight miles inland from the river—and the western dip-slope, formed by the Beavertail limestone, is clearly discernible from the river, all along the Long Reach.

Towards its southern end the course of the anticline presumably takes a slight turn, bringing it to the river side at Bear Mountain, which is a conspicuous anticlinal mass, 1500 feet high, nine miles north-west of Fort Norman. Here the anticline pitches down to south-eastward. It is on the flank of the Wolverine Anticline that the Discovery Oil-well is located.

The Other Three Main Anticlines.—The other three anticlines are of very similar character and need not be described in detail here. Only the northern part of them was mapped, and it has not yet been ascertained whether they also turn south-eastward and continue parallel with the whole length of the Wolverine Anticline.

Other Major Folds.—Besides the above mentioned, there are in this

The Wolverine Anticline, exposed in the river banks at Carcajou Mountain. The axis trends along the cliff; and the crest of the arch of Beavertail Limestone is about three-quarters of the way up. The steeply inclined bed of limestone, which forms the face of the

region two or three other anticlinal hills on the west side of the river, which may, or may not, be continuations of the same folds.

Minor Folding.—On the flanks of the main anticlines, and also in the surrounding territory, there are many minor undulations which may be of considerable importance in determining the position of oil pools.

The Lowland West of the Limestone Mountains.—On the south-west side of the Long Reach there is low, flat land, covered by dense forest and muskeg, extending to the front range of the Mackenzie Mountains, which are twenty-five miles distant from the river.

Probably this area is, in the main, a synclinal, and its surface is formed by the soft Camp Creek Series and overlying Cretaceous beds. But it is also possible that certain important folds may traverse this area, though making no topographic features because their limestone arches are below the level of the land. In any case minor undulations most probably occur.

North of the Limestone Mountains—Ramparts to old Fort Good Hope.—After passing Beavertail Point, where the last of the Mountain Anticlines is crossed, another twenty-five miles brings us to the Narrows and to the gorge known as the Ramparts.

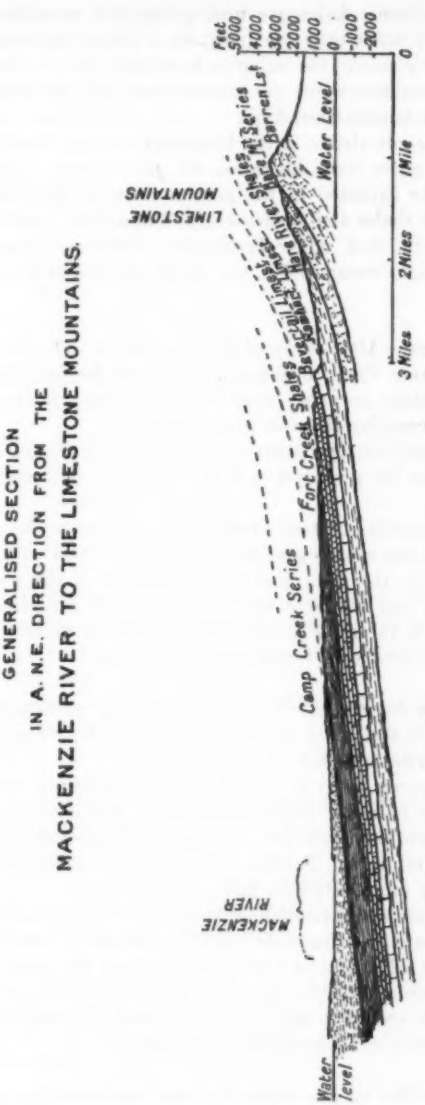
Here the Rampart limestones and Hare River Shales are amply exposed in cliffs 200 feet high. The exposures continue for about 120 miles, as far as the old site of Fort Good Hope, where there are cliffs of the bituminous Fort Creek Shales. But all these beds are nearly horizontal; and in this area no visibly folded rocks are seen.

VII. The Occurrence of the Petroleum.

Bituminous Rocks.—It was the remarkable character of the Fort Creek Shales and Beavertail limestone, rather than the oil seepages, which led to a favourable view of the prospects in this field.

For here, extending over a large region, we have 1000–1500 feet of highly bituminous rocks, which obviously are a potential source for the preservation of a great quantity of petroleum.

These limestones and shales are black with bituminous material, which appears to be present, not as a migratory, but as a fixed constituent. In some places where these beds are much exposed, the bituminous odour is so strong that it may be noticed at a distance of half a mile.



GENERALISED SECTION
IN A. N.E. DIRECTION FROM THE
MACKENZIE RIVER TO THE LIMESTONE MOUNTAINS.

The bituminous shales are undergoing slow combustion at their outcrop—and often they are burnt to a bright brick-red colour, or even to a grey colour, becoming so hard that they clink when struck. In several localities there are conspicuous cliffs of these bright red rocks, over a hundred feet high.

Fluid oil is not visible in the bituminous rocks, though where they pass under water some liberation of gas is seen. But oil might reasonably be expected in the porous beds of the overlying thick series of clay shales and sandstones, and also there was a good chance that at depth, and under favourable structure, accumulations of petroleum might occur within the black shales and limestones themselves.

Oil Seepages.—After study of the bituminous beds, the sands of the overlying Camp Creek Series were searched for oil. At each place examined, either seepages were found, or the presence of oil was detected on crushing the rock under water.

The principal seepages occur on the shores of the Long Reach, where the river flows for seventy-five miles along the outcrop of the Camp Creek Series.

Near the mouth of Camp Creek (which at first we called Oil Creek) the seepages are conspicuous for a distance of two and a half miles. On digging in the river gravel, the outcrops of the green oil-sands are exposed, and the oil could be collected in considerable amount. Further out in the river much oil rises up to the surface of the water, and in winter it collects, forming pools on the ice.

Favourable Structures.—From the foregoing particulars it will be seen that—as stated by me here in 1915—the geological conditions are highly favourable for oil.

Extending over many thousands of square miles we have a thousand feet or more of richly bituminous beds. And overlying these rocks there are two thousand feet of shales and sandstones, from which seepages of oil arise. Further, this mass of petroliferous deposits is traversed by large anticlinal folds.

The high parts of the anticlinal hills are not now favourable territory, for there the oil-bearing beds have been denuded away. But on the flanks of the folds, and on certain low parts of the crests, and also on the minor structures, the petroliferous beds are more or less intact.

Thus there are many places where satisfactory structural conditions occur and pools of oil are likely to be found.

The Oil.—The oil has a paraffin base and is of high quality. The

seepage oil, obtained on digging in the outcrop of the Camp Creek beds, has a greenish black colour, and a strong paraffin smell. The specific gravity is ·905. The crude oil from the well is of light colour, low specific gravity, high gasoline content, and low cold test.

An analysis made at the Alberta University has been quoted as follows:—

Specific gravity	·845 (36° Beaume)
Distillation 70°–150° C.	22·5 per cent
150°–300° C.	38·5 „
300°–350° C.	33·9 „
350°–375° C.	4·1 „
Loss	1·0 „

Thus in commercial terms the oil consists of

Gasoline	22·5 per cent
Illuminating oil	38·5 „
Light lubricants	33·9 „
Medium lubricants	4·1 „

VIII. Exploitation.

Explorations.—Within the region here discussed, the petroleum appears to have been first recorded about a century ago, by Sir John Franklin, who saw, near Bear Mountain, "sulphurous springs and streams of mineral pitch."

Also, for the past fifty years or more, a "tar spring" far inland from the river, has been known to the Hudson Bay Company's men at Fort Good Hope, who have utilized this seepage oil for tarring their canoes.

In 1887 an exploration of the Mackenzie Basin was made by R. G. McConnel, who reported* the occurrence of bituminous or petroliferous rocks throughout the valley.

From that date onward no further geological study of the region was made until the investigation by the author, in 1914, of which the results have been briefly discussed above.

The Discovery Oil Well.—It was not until 1919 that a drilling outfit was conveyed into the North-West Territory, the oil claims having been acquired by the Imperial Oil Company, who were conducting an exhaustive search for oil throughout Canada.

* Geological Survey of Canada. *Annual Report*, 1888-9.

The location of this first test well was chosen in 1914, as a site where a hole of moderate depth could not fail to penetrate the several petroliferous formations which had been found.

The well is on the river bank about half-way down the Long Reach, near the mouth of Camp Creek, where there are copious seepages of oil. Geologically speaking, the location is upon the outcrop of the lower measures of the Camp Creek Series, low down on the south-west flank of the Wolverine Anticline, about eight miles from the axis of the fold.

It was clear that the oil rocks would lie rather shallow here, but by refraining from going further "down the dip" there was less risk of finding the beds occupied by water, and also there was less chance of failure to reach the desired horizons occasioned by engineering difficulties in such a remote country.

The well was drilled during the summer of 1920. Almost from the start oil was coming into the hole; and before a depth of 100 feet was reached, a yield of five or ten barrels a day could be obtained.

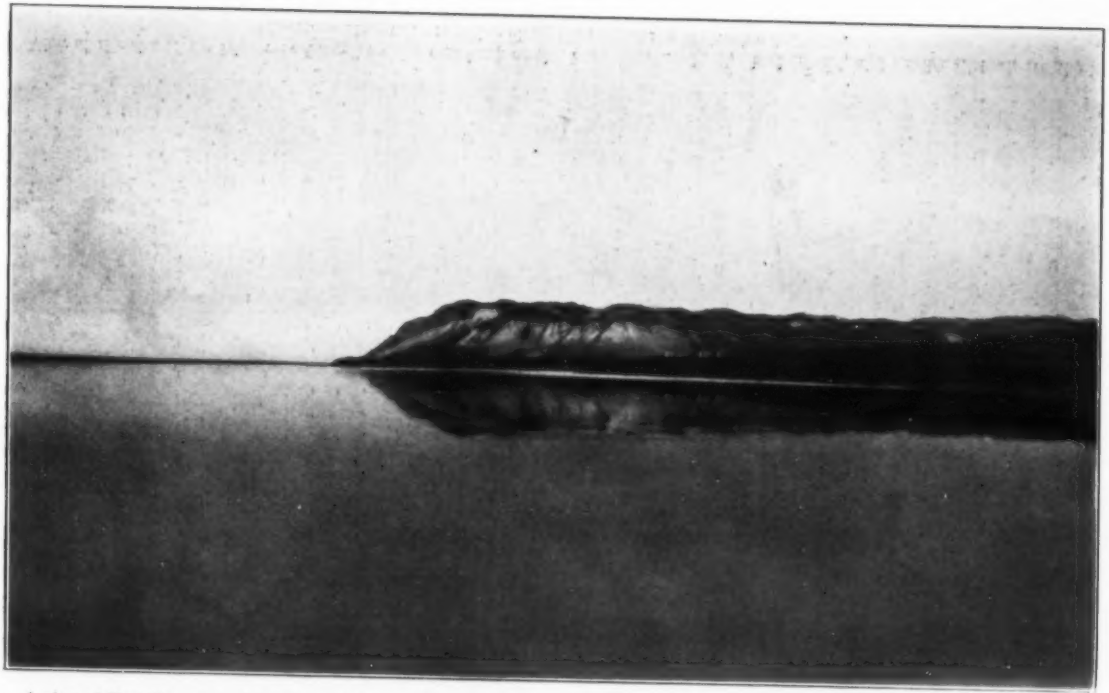
After passing from the Camp Creek Series into the dark Fort Creek Shales, the oil showings still continued, until at a depth of 783 feet, a strong flow of oil was encountered which spouted to a height of seventy feet. After about ten minutes the well was capped. Some hundreds of barrels of oil issued from the well before it was finally shut in, but no dependable estimate of its capacity can yet be made. It is thought that the initial output will be at least 500 barrels a day.

Whether or not this first well will settle down as a steady, large producer yet remains to be seen. And, in any case, many more wells must be drilled before the importance of the field is fully proved.

But progress in the West is swift. A number of drilling machines already are on their way to the north—and during the coming summer the Mackenzie oil-field will be the scene of much activity.

The President said the paper was a most interesting, instructive and very hopeful one in relation to the oil-fields of North-West Canada. The importance of that region, which was probably one of the most promising areas in connection with oil in the whole of the British Empire, could not be overestimated, seeing that the output of petroleum in the Empire was so small in comparison with the general output of the oil-fields of the world, and it was a matter of vital importance to it to develop to the utmost all possible sources of supply. On the whole, Canada had been rather a disappointment in the matter of oil production; there had been a consistent decline in the output of oil in the eastern parts, and the author and others who knew the north-

View of the site of the Discovery Oilwell on the east bank of the Long Reach. In the background, eight miles distant, are the Limestone Mountains trending along the axis of the Wolverine Anticline.



A view of Fort Norman and Bear Mountain, on the east bank of the Mackenzie River. *Photo by Dr. Bosworth.*

Between the village and the mountain lies

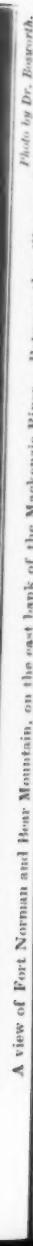

A view of Fort Norman and Bear Mountain, on the east bank of the Mackenzie River. Between the village and the mountain lies

Photo by Dr. Bosworth.

west district well had always held very favourable opinions as to the possibilities of those areas. Oil had been struck, and it had been obtained in the form of a gusher, and the author had stated that it was of a paraffin base type and had a low setting point. That, he thought, might have some important bearing on the vital question of how the oil was to be brought to civilization from such remote distances, if it was proved that it existed in large quantities. Enormous distances were involved. The author had mentioned that it would probably be necessary to put down a pipe line for the transmission of oil, and that raised a very important point in his mind in connection with the setting point to which the author had referred. In those regions the temperature was often 40° below zero, and if the oil was sluggish at such a temperature it was quite probable considerable difficulty would be experienced in dealing with the oil by means of pipe lines. That was a subject on which he hoped the author would further enlighten the members. There were many present at the meeting who were familiar with Canada, notably Mr. Cunningham Craig, whose paper before the Institution in 1915 had been referred to, and it was fitting that on the present occasion Mr. Cunningham Craig should open the discussion on Dr. Bosworth's paper.

DISCUSSION.

Mr. Cunningham Craig said he desired to express the very great pleasure of all the geologists present at the meeting at seeing the author again amongst them, and also the pleasure the members in general felt in at last hearing a paper at the Institution of a purely geographical and geological character. It was a very long time since a paper belonging to that branch of petroleum technology had been presented to the Institution. The author had shown a most interesting collection of lantern slides illustrative of the country, but he wished he had shown a little more of the geology, because there were a great many points that the author had not dealt with. He was sure the author must know a great deal more about the Mackenzie oil-field than he had stated. For instance, he would have liked to have heard more from the author with regard to the important scientific question of where the oil really came from. He gathered the author held the opinion that it was indigenous to the Devonian, but he had not definitely stated so. That was a very important point in connection with the future of the field. In Manitoba the Devonian was not oil-bearing; it was covered by a Cretaceous formation, which had been oil-bearing in that instance, but was not oil-bearing now, because the structure was not favourable. The Devonian was also largely known in the Rocky

Mountains, where it was thrown into beautiful folds, and it was not oil-bearing. It was covered there by a Cretaceous formation in the carbonaceous not the oil-bearing phase. It was known, also, that on the Athabasca River wells had been drilled through the lower Cretaceous, where it was very richly oil-bearing—(the Athabasca tar sands) not in a favourable structure, right into the Devonian—and some very nice filtered oils had been obtained from those wells. He had seen the oil and the logs of the wells. But the question arose with regard to this northern field as to whether the filtered oil was really of Devonian age or whether it had entered the Devonian from the Cretaceous, which had been removed by denudation. In many hundreds of square miles of the northern territories thick oils were found in joints in the limestone, and it could be proved that that oil had entered it from the Cretaceous. He thought the author might have given a little more information upon that point, which was a very difficult but a very important one. From the analysis and the low setting point the oil was pretty obviously a filtered oil—he thought every geologist would admit that—and it seemed possible that the oil had entered the lower formation, where, no doubt, it had been preserved more easily and concentrated by the structures which the author had illustrated. But if it was a filtered oil, even although wells might be obtained, shallow wells or even deep wells, there was not likely to be any very large or long-continued production unless it was possible to tap the oils right in the crests of anticlines and not down the flanks of them as the new well had been drilled. The structural evidence did not seem very favourable, and after the illustrations the author had shown he thought conclusion must be come to that the importance of this new oil-field had been, perhaps quite inevitably, rather exaggerated in the press. If, however, the author could prove that the oils were indigenous to the Devonian, that they were coming up from lower strata in the Devonian and that they were not merely absorbed from higher strata which had since been removed, there would certainly be a very much more favourable prospect for the field. Personally, he would like to know, for instance, just what the percentage of impregnation was in the rocks that were impregnated—in the shales especially. It also might be possible to discover by microscopic examination whether adsorption had taken place to any extent, and further evidence might be found in that way as to the light filtered oil that had been obtained. He did not like to make any predictions, but only to ask for a great deal more information upon the subject.

Dr. H. M. Ami (Paleologist of the Geological Survey, Canadian Department of Mines) said that any subject referring to Canada was of great interest to him, especially if it referred to its geological possi-

bilities. When Mr. Camsell, the Deputy Minister of Mines, showed him in Ottawa last summer samples of the oil from the Mackenzie district he was greatly delighted, because it was as far back as the '80s that he became interested not only in the strateography and chronological history of the various formations that existed in Canada but in the materials which they contained, especially the gas and oil-fields that Canada was then developing, not only in Ontario but in other provinces, and even in Newfoundland. The drillings from all those various places were sent to him, and whenever fossil remains indicating certain horizons and the possibility of obtaining materials of economic value were discovered they were also placed before him. Mr. Cunningham Craig, who had presented a very interesting phase of the problem, had referred to the Manitoba Devonian formation. It was well known that the Devonian formation in Ontario had yielded oil. In 1858 the first oil wells of Ontario were sunk, and yielded a very fair amount of material. They were not producing very much at present, but they were still producing a certain quantity. But the Devonian of Manitoba was not like the Devonian of southernmost Ontario, and in that respect had not been found to be oil-bearing so far. He desired to say, however, that from his examination and handling of hundreds of specimens from the Mackenzie district, and after seeing the collection which Mr. Kannicott made, the Mackenzie Devonian was much more like the Ontario Devonian than like the Manitoba Devonian. He well remembered seeing the coral formation of Ontario with the petroleum within the very corals themselves, so that they were intimately associated, and similar characters of preservation were to be found also both in the Ontario and the Mackenzie Devonian. The Department of Mines at Ontario was looking most favourably on the field as one which would produce material of economic value to the country. Just as Great Britain and France, during the war, used as many of the oil-fields of the world as they could in order to win the war, it was the duty of Canada to seek and find all the materials of economic value that were in her own territory in order that the peace work of reconstruction might be carried on. As would be seen from the map, in the Mackenzie district of Canada, north of Alberta, the Devonian formation ran practically underneath where the Mackenzie district was. The Mackenzie River itself ran over it for hundreds and hundreds of miles, and wherever the Cretaceous formation overlaid it the Devonian also might be tapped in that region. He was not a prophet, but he believed it would probably be found that the oil came from the Devonian. He hoped that would be proved conclusively; certainly he had every reason to think that it was found in that formation. The tar sands and other oil-bearing deposits in the country were very extensively developed, and investiga-

tions had been made, and were still being made, as a result of which the country would no doubt in the future be able to produce materials of economic value. The enormous extent of the paleozoic and Cretaceous rocks in the Mackenzie district bid fair to give an oil-field there of great importance, and also the gas wells of Alberta. Whether oil would be found in large quantities still remained to be seen, but gas was there which contained helium. Those materials must be looked after as part of the assets of the Empire. It had afforded him much pleasure to listen to the paper and hear what was being done, and what was likely to be done in the future, in the Mackenzie district.

The geological work of G. M. Dawson, of R. G. McConnell, of J. B. Tyrrell, of D. B. Dowling, of Eugene Coste and other Canadian geologists has shown that there exists in that portion of Canada oil-bearing strata which deserve to be investigated and proved. Moreover, if, owing to the long distance from the main thoroughfares of Central Canada, from the three great railway arteries of the Canadian Dominion these oil reserves be not utilized at once, their value and significance will soon be recognized. In a new country like Canada every discovery of economic importance, in the form of metal or mineral or fuel leads to enterprise, settlement and undertakings of various sorts which often lead to most rapid development in what at one time was considered a very remote territory.

Dr. J. A. L. Henderson said that he had just returned from a visit to Western Canada and realized the relative inaccessibility of the region in the North-West described by the author, and which had aroused so much interest on account of the discovery of a flowing oil well near Fort Norman. Probably no person in the audience had visited those regions, and whilst that fact rendered intelligent criticism difficult, the early presentation of a paper on the subject by a geologist of standing was a service to the Institution and to the Empire. The author was to be complimented on the series of excellent photographs exhibited and on the geological summary; for great natural difficulties face explorers in those parts, with limited time at their disposal. He would ask if the author had examined the underlying Silurian beds which appeared on the eastern flank of the Devonian basin and which also, he believed, were exposed as inliers in several widely separated localities along or near the Mackenzie River, and particularly associated with the so-called Limestone Mountain range. Information as to the attitude of these beds towards the overlying Devonian, their folding and their lithological characteristics would be of great interest not only in regard to their oil-bearing possibilities but also to the consideration and study of the oil found in overlying formations, particularly of the so-called filtered oils. The crude petroleum from the

Fort Norman well which he had examined appeared to have the normal characteristics of Devonian oils such as are found elsewhere, but the excessively low setting point of the oil—about minus 70° F., he understood—is of extraordinary interest and did not appear to be compatible with the character of a paraffin-base oil. Such a low setting point was of the greatest practical value in connection with the pipe-line transportation problems associated with commercial exploitation of the area. He thought that the author had wisely pointed out that the oil discovery which had been made at Fort Norman did not establish that profitable oil-fields existed, although it is an indication of great value as to the possibilities of this great territory.

Certain of the structures which had been shown were too strongly folded to be considered as favourable, in Paleozoic formations; but in view of the general structure of the wide geological basin, there appeared to be abundant room for the finding of more favourable folding at a distance from the highly folded area. As a matter of general interest he would like to have the author's views on the relation of the Devonian oil to that of the overlying Athabasca tar sands. It has been contended by certain geologists who have great local experience, that the oil of the tar sands has been derived from the underlying Devonian, but to the speaker the characteristics of the two types of oil did not appear to support this.

Dr. W. R. Ormandy said that there was a well-known saying that the beginning of wisdom was to know where one was ignorant. He made no claim to a knowledge of geology, but he had had a little to do with oil shales. He would like to know, therefore, whether the oil shales which were found in such enormous quantities in the area dealt with by the author contained oil in a form in which it could be extracted by the ordinary type of solvent, or whether it was in a form which had to be subjected to heat; i.e. whether it was present as a kerogene or as an oil, because he thought that would have a considerable bearing on the problem. Perhaps the author had carried out experiments, or knew of experiments which had been carried out, in that direction, and if so any information he could give on the subject would be of great interest.

Dr. T. O. Bosworth, in reply, desired to thank the members for the kind reception they had given to his paper. Mr. Cunningham Craig had raised the very interesting question of the origin of the oil. The author could not agree with him that the oil was not indigenous to the Devonian. There might be instances in other parts of the country, such as in the Devonian on the Athabasca River, where oil had passed into crevices in the Devonian rocks from overlying tar sands of the Cretaceous; but in the Mackenzie region the oil bearing forma-

tion lay at a considerable depth in the Devonian. The bulk of the Cretaceous deposits had been removed a very long time ago; and only remnants were now to be seen. These were not similar to the oil-bearing Cretaceous deposits of Alberta. Further, these Cretaceous rocks were largely composed of fragments of the black bituminous Devonian shales. Since Mr. Cunningham Craig was one of the pioneers of the theory of the origin of oil from vegetable "kerogen" in shales, it would be interesting to have his opinion on the specimens of these Devonian plant-bearing black shales. Perhaps a microscopic study would reveal whether the material in them was "kerogen," or whether it was a bituminous matter which had invaded the shales. The same speaker also had mentioned that the structure in the region was not entirely satisfactory, on account of the large anticlines having been so much denuded. Nevertheless, some parts of the anticlines were much less denuded, and there were also places where the arches of limestone lay deeper underground, and had not been developed out by denudation.

It was a very great pleasure to the author, and he was sure to all the members, to hear the remarks made by their distinguished visitor from the Canadian Department of Mines, who had discussed the general situation in such an able and interesting manner. In the paper it was made clear that the oil in the Mackenzie region was seen and recorded many years ago by R. G. McConnell, of the Canadian Geological Survey, whose splendid exploration work was described in one of the reports of the Survey. By him the attention of the Canadian Government had been called to the fact that there was a great petroliferous formation in the Mackenzie Valley.

The Silurian formation in the Mackenzie region about which Dr. Henderson enquired, was at present very little known. The mountain ranges far back from the river are still practically unexplored. The Franklin range, north of Great Bear River, had been visited recently by a geologist, who brought back many typical Silurian fossils. The Silurian might be exposed also in the Mackenzie Mountains, twenty-five miles back from the river, west of the present drilling field, but at present little or nothing is known of the geology of that mountain range. It is not unlikely that the Silurian and Ordovician are represented in the thick series of barren limestones which had been shown at the bottom of the table of formations. The question had been asked whether the oil was in sandstone or limestone. In the Camp Creek Series the oil was in the sandstones. But in the black, Fort Creek shales, the oil was contained, presumably, in porous shale, or in sandy limestone bands. It remained to be seen what would happen when the drill went lower and the bituminous Beavertail limestone was

struck. With regard to the effects of low temperature, the chemists had carried out the regular tests, as applied in Canada, on the residue from distillation, and pronounced the oil as "low cold-test oil." The crude oil will remain entirely liquid at Arctic winter temperatures. The author fully agreed with Dr. Henderson that one well by no means proved the field. It was, however, a first-class indication, and those concerned were in a state of hope and expectation. The origin of the oil in the tar sand of Athabasca was an obscure question. That district is 750 miles distant from the Mackenzie oil-field. The Devonian oil rocks of the great Slave Lake region, however, are nearer; and it is possible that some of these petroliferous beds may extend still farther southwards, though not exposed. Actually underneath the tar sand the Devonian is not petroliferous though it contains some gas. But the oil in the tar sands is asphaltic, and is very different to that of the Devonian. He considered that at present the balance of evidence was in favour of the oil in the tar sand being truly a Cretaceous oil.

The author did not agree with one of the speakers who regarded the oil in the Discovery Well as a filtered oil. Of course all oil that comes out of rocks is, in a sense, filtered oil, to some extent; but this crude oil in the Mackenzie oil-field is similar to the crude oil of other oil-fields in Palæozoic rocks.

In regard to Dr. Ormandy's question, no laboratory experiments on the black shales had been made; but on retorting some of them in a rather crude apparatus he had obtained a yield of oil. The quantity, however, was not great enough for these shales to be of economic value as oil-shales. He would like to see Dr. Ormandy's suggestion carried out of making experiments with solvents; and it might then be possible to show whether oil had been generated from these shales or whether any fluid oil had invaded them. But in either case, personally he felt no doubt that the petroleum was indigenous to the Devonian formation.

The President, after announcing that the Council would welcome written contributions to the discussions on papers, which should be sent in as early as possible in order that they might be submitted to the authors for reply, proposed a hearty vote of thanks to Dr. Bosworth for his most interesting paper and expressed the appreciation of the members of the work he had done in a far-off part of the Empire.

The resolution of thanks was carried by acclamation, and the meeting terminated.

The Fifty-seventh General Meeting of the Institution was held at the Royal Society of Arts, John Street, Adelphi, London, W.C., on Tuesday, May 10th, 1921, Professor J. S. S. Brame (President of the Institution) occupying the Chair.

The President briefly introduced the reader of the paper (**Professor P. Carmody**) to the meeting.

The following paper was then read :—

Trinidad as a Field for the Study of the Origin of Petroleum.

By P. Carmody, F.I.C. (late Government Analyst and Professor of Chemistry, Trinidad).

Within a comparatively limited area in the small island of Trinidad there are so many deposits more or less closely allied to substances of the organic carbon type, that they are deserving of careful investigation and comparison by geologists and chemists who are interested in the study of the origin of petroleum, or who are in the employment of governments or capitalists whose main object is the successful development of remunerative areas from which oil can be obtained. Up to the present, efforts have been concentrated mainly in locating payable pools of petroleum, and with considerable success ; a systematic study of the origin of petroleum has been more or less neglected and consequently has been less successful.

Until the origin of petroleum is better understood, and this is only possible through systematic and comprehensive investigation by experienced observers, the search for it will be accompanied by an undesirable amount of disappointment and failure. It is because I believe that Trinidad is a most suitable place for such an investigation that I have compiled these notes.

Asphalt and Similar Solid Deposits.

I will first refer to these because asphalt is, and has long been, a prominent feature of the so-called mineral deposits of Trinidad. The " Pitch Lake " is so well known to you that it need only be mentioned. Its origin remained conjectural until Mr. Cunningham Craig's Report appeared in Council Paper No. 60 of 1907 (Trinidad). That it is the residue of liquid petroleum, after a prolonged process of natural evaporation, is an easily accepted conclusion. Though it is a mixture of asphalt, sand and water, its composition is remarkably uniform. It has been described as an emulsion with colloidal properties. It is

Table A. Analysis of Lake (" Soft " and " Hard ") Asphalts (Trinidad).

Table A. Analysis of Lake ("Soft" and "Hard") Asphalts (Trinidad).

Lake Asphalt.	% Composition.				Sulphur % (as S.).	% Bitumen.			Ash: % Sol. and Insol.			% Sulphates in the Ash (as SO_3).	Fractional Distillation.								Sp. Gravity.	Flash-point (Open Vessel).
	Water.	Ash.	Organic Matter.			Total Sol. in Carbon disulphide.	Sol. in Petroleum Ether.	% of Total: Sol. in Petroleum Ether.	Sol. in Water.	Sol. in dilute HCl.	Insol.		To 150°C.		150-300°C.		Above 300°		Coke and Ash.	Steams and uncondensed gases.		
			Bitumen.	Other.									Water.	Oil.	Water.	Oil.	Water.	Oil.				
"Soft"	29·04	24·12	45·60	1·24	2·38	45·60	24·00	52	0·72	4·20	19 20	0·19	9·0	1·0	0·5	8·5	—	15·0	39	27	1·25	About 170° C.
"Ordinary" or "hard"	26·04	27·52	42·00	4·44	2·44	42·00	21·60	51	0·80	5·08	21·64	0·24	6·5	0·7	4·5	2·8	—	14·5	41	30	1·37	About 200° C.
do.	21·40	20·68	42·02	6·90	—	—	—	—	0·98	4·44	24·26	—	—	—	—	—	—	—	—	—	—	—
do.	27·38	27·38	40·25	4·99	—	—	—	—	0·90	4·04	22·44	—	—	—	—	—	—	—	—	—	—	—

Gas from the Pitch Lake.

	No. 1.	No. 2.
Sulphuretted Hydrogen	1·0	1·78
Carbon dioxide	19·0	12·02
Unsaturated hydrocarbons	0·2	1·40
Carbon monoxide	1·1	0·20
Marsh gas	1·7	not determined.
Hydrogen	3·8	
Nitrogen (by difference)	73·2	
	100·00	

Water from Centre of the Pitch Lake.

Total dissolved gas, absorbed by Potash	87·100 cc. per litre.
Dissolved Hydrogen Sulphide	0·007 g. "
Sulphur as Alkaline Sulphide	0·038 g. "
Total Sulphur other than Sulphate	0·144 g. "
Total Solids (dried at 110° C.)	1·288 per cent.
Water of hydration (loss at 110 to 180° C.)	0·026 "
Loss on ignition (above 180° C.)	0·078 "
Lime	0·011 "
Alkalies as Chlorides	1·104 "
Sulphates as SO_3	0·022 "
Phosphates as P_2O_5	0·005 "
Iron	tr.

found in two forms—" soft " and " hard " or " ordinary " in the lake. The " soft " is found towards the centre of the lake within a radius of 100 feet, and is in slow but constant motion from below, upwards and outwards; the " hard " is found around the central area and extends to the borders of the lake which covers an area of over 130 acres. Ordinarily the " hard " variety has no motion, but it moves, under pressure, in the direction of least resistance. Analysis shows a small, but distinct, difference in composition between the " soft " and the " hard." *See* Table A.

The borders of the Pitch Lake are fairly well defined; and beyond one edge there has been a comparatively large and steady downward movement of asphalt towards the sea. This deposit is locally known as " land asphalt." Its composition is not uniform, and the differences between it and " lake asphalt " are shown in Tables A, B and C.

TABLE B. ANALYSIS OF TRINIDAD LAND ASPHALT.

(Taken at intervals between the Lake and the seashore about 1 mile distant.)

From near the Lake to the Sea-shore.	Loss on Ignition, Bitumen, Etc.	Water.	Mineral Matter.			
			TOTAL.	Soluble in Water.	Soluble in HCl.	Insoluble.
Near Lake	45·84	26·46	27·70	0·78	4·04	22·88
to	45·78	26·46	27·76	Not	determi	ned.
↓	43·42	29·90	26·68	0·48	4·70	21·50
	44·18	26·42	29·40	Not	determi	ned.
near Sea.	45·48	26·36	28·16	0·62	3·84	23·70

Note.—These represent the best grades of land asphalt only.

" Land asphalt " is apparently a bituminous mixture which may have been, at one time, of the same uniform composition as " lake asphalt," but which has mechanically carried with it, in its downward course, some of the loose earthy matter through, or over which, it has passed. Though there is this difference in composition, the asphalt from the Pitch Lake and from adjacent land deposits is usually pitted with cavities, and is known locally as " cheese pitch."

There are small and scattered deposits of two other varieties, viz. " glance pitch " and " iron pitch," the composition of which is given in Table D.

TABLE C. COMPARATIVE RESULTS OF ANALYSIS OF SEVERAL KINDS OF ASHPHALTIC DEPOSITS (TRINIDAD).

TABLE C. COMPARATIVE RESULTS OF ANALYSIS OF SEVERAL KINDS OF ASHPHALTIC DEPOSITS (TRINIDAD).

	Liquid Asphalt.	Semi-Liquid Asphalt.	"Soft" from the Lake.	"Hard" from the Lake.	"Hard" from Lake Steam dried.	Ordinary "Land" Asphalt.	"Cheese" Pitch.	"Iron" Pitch.	Inferior Asphalt. — Seashore.	"Glance" Pitch.	Manjac.	Liquid Petroleum. — s.g. ·9226 Fl. pt. 27° C.
By Heat—												
Volatile matter	92·97	81·84	54·54	53·30	52·92	47·70	49·35	50·60	33·70	74·80	59·78	95·80
Fixed carbon	7·01	10·13	9·62	10·26	10·30	9·85	10·80	11·20	8·00	24·20	37·76	4·20
Ash	·02	6·77	30·87	35·24	36·78	33·84	36·35	37·60	52·35	1·00	2·42	tr.
Volatile factor	13·28	8·08	5·68	5·20	5·14	4·85	4·56	4·49	4·20	3·09	1·58	22·80
By Solvents—												
Petrolene	89·9	65·36	44·43	39·22	38·37	35·23	34·99	36·49	30·47	34·64	17·06	nearly all
Asphaltene	10·1	27·11	14·75	16·69	16·81	10·42	11·72	17·03	7·88	64·84	80·70	tr.
Organic (non-bituminous)	—	1·03	8·55	8·95	8·34	19·64	16·99	9·13	9·61	—	0·51	—
Sulphur	2·66	2·88	3·62	3·81	4·13	3·55	3·84	3·86	3·20	5·12	3·57	1·14
Organic matter and Sulphur to 100 *Inorg.*—												
Volatile matter			176·50	151·3	144·0	141·0	136·0	134·0	64·4			
Fixed carbon			31·07	29·4	28·0	29·1	29·7	29·7	15·3			
Total organic			207·57	180·7	172·0	170·1	165·7	163·7	79·7			
Sulphur			11·70	10·8	11·9	10·5	10·5	10·3	6·1			

TABLE D. ANALYSIS OF "GLANCE PITCH" AND "IRON PITCH."

	Bitumen, %.	Other Organic Matter, %.	Water, %.	Mineral Matter, %.	
Glance .	87·60	Included in Bitumen .	3·48	8·92	Volatile matter =57·67 Coke =29·93%
Iron .	52·80	6·32	0·80	40·08	Volatile matter =50·60 Coke =11·20%

"Glance pitch" appears to have undergone a softening process by which the cavities characteristic of "cheese pitch" have been obliterated; and "iron pitch," which is found in small pockets, appears to have been dried and partly coked by "bush" fires which are fairly frequent. Neither of these is of commercial importance.

MANJAC.

The composition of manjac is very different from that of lake or land asphalt. Mineral matter and water are almost absent, and a nearly pure bitumen results from the peculiar conditions under which it is formed. Table E shows its composition.

TABLE E. ANALYSIS OF MANJAC (TRINIDAD).

Water.	Mineral Matter.	Organic Matter.		Petrolene(Sol.) in Petroleum Ether.	Sulphur.		Locality.
		Bitumen.	Other.				
1·85	1·68	90·00	—	—	3·94		Vista Bella
4·00	4·20	88·88	·04	—	2·6	s.g. 1·125 to 1·13 m.p. 240°C. softening pt. 195° C.	do.
0·85	7·70	90·05	1·40	12·8	—	Depth = 100 ft. (columnar)	do.
6·05	4·0	88·95	1·00	15·2	—	,, 140 ft. (conchoidal)	do.
4·56	4·48	90·60	0·36	15·6	—	,, do.	do.
0·65	4·55	94·80	—	8·8	—	Outcrop	Maraboella
1·50	2·55	95·80	·15	56·0	—	Depth 118 ft. *Centre* of Vein	do.
1·00	2·80	94·80	1·40	9·6	—	,, 125 ft.	do.
0·24	7·80	92·80	—	—	—		Coolie Town
7·88	1·50	84·	6·62	26·6	—		

In distilling heavy asphaltic oils, in the ordinary process of analysis, a residue is left at a certain stage which is indistinguishable from manjac; and this affords a clue to the conditions under which

natural deposits of manjac may have been formed. Manjac is apparently the residue of a liquid or semi-liquid petroleum from which the lighter portions have disappeared by natural agencies in the absence of close contact with water or sand. Manjac absorbs oxygen from air in appreciable quantities (Table F).

TABLE F. ACTION OF MANJAC ON AIR.

	Air in Manjac Mines.		Air after Exposure to Manjac.	
	Vista Bella.	Marabella.	1 week.	5 weeks.
Carbon dioxide	1·40	0·20 to 0·80	0·60	(After exposure to air of Laboratory for 1 week.)
,, monoxide	nil	nil ,, tr.	0·60	
Unsaturated hydrocarbons	0·20	0·20 ,, 0·75	1·20	
Carburetted hydrogen	0·75	0·40 ,, 0·80	nil	
Oxygen	19·00	19·30 ,, 19·60	12·60	
Nitrogen	78·65	78·85 ,, 79·50	85·60	
	100·00	100·00	100·00	

	per cent.	per cent.
Oxygen absorbed	9·00	6·10
,, required for CO_2 and CO	0·09	0·85
,, absorbed and not used in forming gaseous oxidation products	8·01	5·02
Diminution in Petrolene	1·80	1·04

COAL.

The coal deposits of Trinidad are not of commercial interest either in quantity or quality. The composition of some of these is shown in Table G.

TABLE G. ANALYSIS OF COAL (TRINIDAD).

Water, %.	Volatile, %.	Coke, %.	Ash, %.	Bitumen, %.	Sulphur, %.	Calorific Value (Thompson).	Locality.
18·60	—	—	7·40	—	2·48	—	Tururc.
10·45	43·90	38·45	7·20	2	4·57	11·47	Cunapo : 1 foot deep.
12·30	41·45	43·50	2·75	—	1·86	7·16	,, 2 feet ,,
11·80	42·30	40·50	5·40	—	3·80	10·40	,, 3 feet ,,
2·25	48·05	48·70	1·00	24·8	3·01	16·38	Montserrat
3·79	61·25	31·70	3·35	58·0	3·96	14·34	do.
3·75	45·40	45·60	5·25	2·0	2·20	14·33	do.
3·96	45·74	45·98	4·32	—	—	—	do.
14·28	31·72	36·64	23·36	—	—	7·58	Morugu.
11·80	25·55	21·65	41·00	—	—	—	Oropouche—Black River.
17·65	39·35	35·80	7·20	—	3·69	5·58	do.
5·40	42·60	49·64	2·36	6·2	—	—	Piparo.
20·00	29·20	42·52	8·28	—	—	—	Brasso Caparo.
12·65	37·75	40·65	8·95	trace	—	10·75	Sardoo River, Saugre Grande.
13·38	35·69	42·85	8·08	—	—	—	Cunapo.
12·29	36·82	42·57	8·32	—	—	—	do.

The coal deposits so far discovered are not in the neighbourhood of the large bituminous deposits; but they may be worth investigating if it can be shown that the conditions favourable to the formation of

bituminous deposits are unfavourable to the formation of coal, and vice versa. Some of the coals are distinctly bituminous.

Lignite.

There are numerous small deposits of lignite of poor quality, the composition of which is shown in Table H.

Table H. Analysis of Lignite (Trinidad).

Water, %.	Volatile Matter, %.	Coke, %.	Ash, %.	Bitumen, %.	Sulphur, %.	Calorific Value (Thompson).	Locality.
25·75	30·75	36·20	7·30	—	6·14	8·80	Gran Couva.
29·50	32·40	35·30	2·80	0·8	4·89	8·80	Tamana.
3·55	58·45	31·95	6·05	—	—	—	Oropouche.
20·68	39·92	36·80	3·20	—	—	—	Chaguanas.
21·16	43·74	29·74	5·36	—	—	—	do.
20·40	28·00	25·78	25·82	—	—	—	do.
21·56	46·84	26·92	4·68	—	—	—	do.
20·80	24·20	20·64	34·36	—	—	—	do.
24·32	35·68	36·52	3·48	—	—	—	do.
27·24	36·91	32·61	3·24	—	—	—	do.
25·20	37·65	32·35	4·80	—	0·89	—	Brasso Caparo.
33·72	33·48	30·80	2·20	1·6	—	—	do.
25·50	38·27	33·00	3·23	—	—	—	

Coke made from Lignite.

Water, %.	Volatile Matter, %		Ash, %.			Calorific Value (Thompson).	Locality.
3·76	81·92 *Total Organic.*	—	14·32	—	—	9·68	Arima.

1 lb. Lignite gave 4 c. ft. of gas of the following composition :—

Sulphuretted hydrogen	0·5
Carbon dioxide	12·3
Oxygen	2·2
Ethylene	1·4
Carbon monoxide	53·4
Hydrogen	3·9
Residue (mainly marsh gas and nitrogen)	26·3
	100·0

Some contain bitumen, others do not. They usually contain large percentages of water, and are sometimes slightly bituminous.

Other Solid Carbon Deposits.

There are indications of graphite in several districts, and one sample of ozokerite was submitted to me for analysis and was stated to be of Trinidad origin.

Liquid Deposits.

The discovery in recent years of liquid petroleum in commercial quantities has led to fairly rapid exploration, and surface deposits have been located in many places, but mainly in the southern half of

the island. These have, so far, conveniently arranged themselves for the most part along three east and west lines running adjacent to each other. From the proximity of these deposits and within so small an area, it might be thought that the composition would be nearly uniform. But this is not so. There are light oils as fluid as kerosene, others heavy and thick and semi-solid; some have a paraffin base, some an asphaltic base, and some practically free from asphalt or paraffin. This makes the problem of their origin much more interesting. The analytical results obtained from typical samples of these oils are given in Table I.

TABLE I. ANALYSIS OF LIQUID AND SEMI-LIQUID OILS (TRINIDAD).

Sp. gr. $\frac{26°C.}{26}$	Flash point °F.	Fractional distillation. Below 150°C.	150°C. to 300°C.	Above 300°C.	Residue and loss.	Sulphur.	Mineral Matter.	Locality.
·808	—	41	37	19	3	—	—	Tabaquite.
·796	—	35	37	26	2	—	—	do.
·896	below 50	15	44	36	5	0·41	—	Guayaguayare No. 1 Well.
·826	—	38	40	17	5	0·62	0·01	do. do.
·884	—	15	49	30	6	0·30	0·01	do. 2
·908	—	13	31	43	13	0·83	0·04	do. do.
P ·852	—	14	46	36	4	tr.	nil	do. 3
·934	—	1 (OH_2)	21	68	10	0·47	0·08	do. 4
P ·868	—	13	44	39	4	—	—	do. 8 (semi-solid).
·867	over 154	tr.	73	25	2	tr.	nil	Lizard Spring.
·840	86	12	81	7	—	—	nil	do.
·841	—	53	45	—	2	—	nil	do. River.
·935	77	1	43	38	18	—	0·40	Aripero (Old).
·972	—	14	73	—	13	—	—	Mayaro, Pilot R.
·972	—	27 (OH_2)	50	3	20	—	1·68	do. Ginipar.
—	—	10 (OH_2)	29	27	34	—	3·36	Lagoon Bouff (semi-solid).
—	—	26 (OH_2)	53	3	18	—	0·72	do. (liquid).
—	—	23 (OH_2)	46	tr.	31	—	4.94	Piparo (semi-solid).
—	—	—	25	43	29	—	0·24	Pt. Ligoure (semi-solid).
·960	—	8	45	29	18	—	0·04	Guapo, 16 ft. depth.
·938	—	6	27	58	8	—	0·13	do.
·950	—	13	36	32	18	—	0·02	La Brea, oil rock, shallow boring.
·918	—	7	29	52	12	—	—	do.
—	—	24 (OH_2) + 2 (spirit)	42	16	17	1·07	0·79	Tarouba Hill { Bitumen = 73·18 Petrolene = 60·44 (Paraffin = 25%)
P ·840	—	tr.	50	49	1	—	nil	
P ·838	—	5	55	39	1	—	—	Nariva.
P ·836	—	1	50	45	4	—	—	do.
·985	—	16 (OH_2)	13	58	13	—	0·41	
·988	—	2 (OH_2)	9	80	9	—	0·52	
·908	95	9	42	44	5	—	—	Barrackpore.
·876	—	23	37	35	5	0·03	—	do. Settlements.
·955	221	1	33	50	16	—	—	
·852	—	26	34	38	2	—	—	Icacos.
·968	—	1 (OH_2)	16	76	7	—	0·21	
·932	—	6	24	58	12	—	—	Silver Stream.
P ·940	—	3	29	60	8	0·77	nil	Palo Seco (Paraffin = 15%).
·963	—	2 (OH_2)	20	73	5	—	0·12	
·908	—	13	27	52	8	0·49	0·12	Point Fortin.
·944	—	—	26	63	11	0·79	0·22	do.
·930	—	10	22	55	13	0·94	0·05	do.
·907	17	13	29	49	9	—	0·14	do.
—	—	9 (OH_2)	28	44	19	—	—	Rock River (Exposed) Morass.
·977	—	6	30	55	9	0·39	0·26	Siparia (Fyzabad).

* P = Solid Paraffin.

Can these oils have been formed from different substances, or have they a common source, and subsequently varied in composition by conditions of environment?

Water.

I am led, by the importance of the connection between salt water and petroleum, to include the analyses of a water from an oil well, and a water from a deep well used for drinking purposes, containing no traces of oil, but not far distant from a productive oil field. They are given in Table J.

Table J. Analysis of Saline Waters (Trinidad).

Locality.	Parts per 100,000.							Nitrogen as Nitrates.	
	Total Solids.	Chlorine.	Ammonia.		Hardness (as $CaCO_3$).				
			Free.	Albuminoid.	Temporary.	Permanent.	Total.		
Montserrat . .	326	71·0	·5160	·0320	1·17	1·95	3·12	nil	1909 April
(Santa Maria Well)	338	72·5	·4550	·0250	—	—	—	tr.	May
do.	306	67·0	·4180	·0200	—	—	—	nil	June
do.	4	0·7	·0016	nil	nil	0·95	0·95	nil	July
do.	44	6·7	·0690	·0240	5·68	0·32	6·00	nil	Aug.
do.	320	70·5	·4190	·0190	—	—	—	—	Sept.
do.	222	6·9	·2240	·0220	2·12	0·48	2·60	·0284	April
(San José Well)	338	72·5	·4550	·0250	—	—	—	tr.	May
do.	96	5·6	·7300	·0220	—	—	—	nil	June
do.	86	5·3	·4720	·0120	7·57	5·14	12·71	nil	July
Sea Water at Port of Spain. *Light House Jetty* .	3,531	2,585	·0126	·0222					
From Mud Volcano. *Princes Town* . .	731*	198·8	·026	·048					
	2506	1238							
					Alkalinity (as Na_2CO_3) = 0·38%.				

* Contain SiO_2, ·027%; Fe_2O_3, tr.; NaCl, ·327; CaO, ·032; MgO, ·012; SO_3, ·048.

Gaseous Emanations.

These take two forms—gentle and eruptive. The former type may be constantly seen rising through the "soft" pitch in the lake, and the air of the manjac mine contains gases other than atmospheric; the latter type may be seen in some mud volcanoes, and was responsible for the large mud island, with an area of about three acres, which was thrown up at a point about two miles from the south coast in November, 1911.

It will be seen from the foregoing that several forms of deposits, of which carbon is the essential ingredient, are available and conveniently situated for scientific investigation. The island is easily reached from

Europe, the United States, or Canada; the total area is small and the oil area much less; roads are well planned and most of them are suitable for motoring; there is a train service from Port of Spain which branches out in three directions towards the principal oil fields; a steamer service round the coast; and a considerable area of land cleared of forest by cultivators and, during recent years, in connection with active oil exploration. Hotel accommodation is fairly good and, for a tropical climate, health conditions are also. There is a Government laboratory provided with the usual appliances for oil testing, and when the agricultural college is built there is likely to be additional facilities for any kind of research work relating to the industrial development of the colony.

My experience in Trinidad compels me to suggest that in an enquiry of this nature team work is essential. Before Mr. Cunningham Craig began his geological work in Trinidad, I had for several years made analyses of samples from deposits of the various types mentioned above. The analyses were made principally for private individuals who, in the first place, were generally unwilling to disclose the exact locality from which the samples were taken; in the second place, each of them was working independently of the others; and in the third place, my reports and analyses were not official and could not be used for any public or other purpose without the consent of those who obtained the analyses. With Mr. Cunningham Craig the position was different, and useful results quickly followed. We were both in the Government service, and he was appointed for the sole purpose of making geological studies of possible oil-bearing strata in the colony. I was able to render him some assistance in the analyses of the specimens he selected for more detailed examination. He collected and linked up the results so obtained, and published them in his Reports which appeared as Council Papers.

Collaboration of this nature between the geologist (or geologists) and the chemist is the only way that points to definite and successful results. One chemist would probably be able to undertake the analyses, in a general way, of all the specimens submitted in the early stages of the investigation, but there cannot be too many geologists employed in field work. At present, and during recent years, there are and have been, many geologists employed in the Trinidad oil fields, but usually working independently for different companies and unable through professional etiquette to collaborate with each other. There must always be, to some extent, between different companies a certain amount of rivalry; but might it not be possible and sufficient to confine this to the commercial aspect, and not only permit, but encourage, collaboration on the scientific aspect?

There are, of course, obvious difficulties to be encountered, but unless they are surmounted we shall lag behind other nations in the development of the oil resources of the Empire. There is much leeway to be made good. In Trinidad our sins of omission were conspicuous. Frenchmen were the first to make a serious attempt (at Aripero) to develop the oil resources of the colony; and the commercial advantages of the Pitch Lake are monopolized and controlled by a company, or companies, in the United States of America. Up to ten or fifteen years ago in Trinidad there were only a few (if any) skilled drillers of British nationality, and an insufficient number of expert oil geologists. A serious effort must be made to secure better conditions.

It is too much to expect that a Government staff of geologists would be provided for the sole or main purpose of studying the origin of petroleum, or that such a staff would be the best for the purpose. As in other industries undertaking research work on modern lines, collaboration between scientific workers and those who are actively engaged in the industrial and commercial development of oil fields is essential. The data obtained by trained observers in the various places where oil is indicated or found are of primary importance, and should be collected in a central bureau controlled by Government, or preferably by a representative body chosen by those who are specially interested in oil. The data so collected should be readily available for reference on similar lines to those adopted by other recently formed research committees.

The Origin of Petroleum.

As to this, there is so much room for conjecture, which in the past has been fully and freely developed, that in a short paper, and at this Institute, it would be out of place to refer to it at any length. In the early days of petroleum, when only a few large deposits were known, and these separated by enormous distances, it is not to be wondered at that theories of a violent origin were propounded. The action of water on metallic carbides is an example of this class. Now, when oil is being found in so many parts of the globe, we must look towards those natural, slow-working agencies, of the existence of which we can produce evidence, for a satisfactory solution of what is admittedly a very difficult problem, and on which there will be for some time yet considerable difference of opinion. It is only by a systematic and comprehensive study of known natural phenomena that we can hope to arrive at useful conclusions. If such conclusions only lead to the exclusion of ill-founded theories, we must then push forward in some other direction.

My view inclines towards a vegetable origin for all the carbon deposits

that occur on or in the earth's crust. The whole of the surface of the earth is, or was at some time, clothed with vegetation, some of which decays and is renewed annually, some at longer intervals; but whatever may be the interval there is a continued increment of organic matter which, over a period of years and a large area of surface, results in a huge accumulation in a modified form. The chemical nature of this vegetation is mainly cellulose, and cellulose contains about 44 per cent of carbon, which is a large contribution towards the higher percentages of carbon found in the best qualities of the coal deposits and other deposits rich in carbon. The formation of peat from vegetable matter takes place in the presence of much water. I am unable to say whether any similar change has taken place in the lagoons in Trinidad; but, so far as I know, peat has not been found.

Coal is also of vegetable origin, and the cellulose from which it is formed was probably physically different from that which produces peat, and it is also probable that the chemical changes took place in the presence of a limited quantity of water.

Lignite also is of vegetable origin, and, like coal, the chemical changes appear to have been influenced by the presence of a limited quantity of water.

When we come to consider the liquid carbonaceous deposits the subject becomes more complicated, as there is no microscopic evidence of cellular structures *in situ*. Their fluidity permits of their downward passage through porous strata and simultaneous separation of any solid particles they may have contained. Evidence of a chemical nature must in such cases be mainly relied on. The deposits are still rich in carbon, but the carbon is in combination with hydrogen in the form of liquid hydrocarbons. Intimately associated with the latter at some time or other are the gaseous hydrocarbons which escape in large quantities from oil wells, just as they do in smaller quantities from coal mines and from marshes.

The composition of cellulose shows that it can supply sufficient carbon and hydrogen to account for the amounts and proportions found in the liquid and gaseous hydrocarbons; but the changes which the cellulose has undergone must have been different from those which produced coal, lignite, or peat. And here we cannot exclude the possibility of the influence of other existing natural agencies whose life functions are associated with the transformation of the dead or dying organic matter in the surface soil. We must consider the action of bacteria (both aerobic and anaerobic) of earthworms, and of the often-mentioned marine organisms in conjunction with the natural processes of decaying vegetable matter. And when they die, we should examine the nature of the residual organic matter in its altered condi-

tion. The actual amount of organic matter converted by these living organisms into other kinds of organic matter must be appreciable, since the processes of assimilation and decay are practically continuous and universally distributed.

Nor can we omit to consider the influence of the presence in plants of other organic substances differing, physically and chemically, from cellulose. Among these are gum, resin, rubber, sugar, starch, albuminoids, oils and fat; and they must exercise some influence on the nature and composition of the resultant carbon deposit. As they are mostly amorphous substances they leave no residues which can be identified by microscopical examination.

The formation of black liquid by hydrocarbons suggests the action of moderately high earth temperatures, high earth pressures and the presence of some water or other diluent.

The presence of an asphaltic base in some oils and a paraffin base in others is difficult to understand unless we assume a difference in the character of the vegetable substances from which the oils are formed.

The presence of water in some oils and its absence in others may be due to some constituent in the former having an emulsifying action. In the presence of large quantities of water the oil would naturally float on it, and in oil wells generally this appears to be the case.

From all oil accumulations the escape of the lighter constituents is more or less continuous, and when confined in wells considerable pressure must result from the gaseous constituents liberated. The effect of this would be to force the liquid portion more rapidly through any porous adjacent strata, and when the gas pressure becomes greater than the weight of the superincumbent earthy layers, the gases rise to the surface with, in some cases, violent eruption. In doing so, it is conceivable that occasionally a vacuum may be formed into which the liquid asphalt is drawn upwards towards the surface, loses its internal heat, and solidifies in that position. I suggest this as a possible explanation of the occurrence of manjac in the Trinidad deposits. Its purity indicates its origin from a clean, heavy asphaltic oil, and the fracture of pieces taken from different parts of the bed shows that solidification took place more rapidly at the outer edges than in the interior.

The eruption of gases that threw up the island off the south coast in 1911 was probably a similar phenomenon. At first the mud rose slowly above sea-level, then the gases escaped with a loud explosion, took fire spontaneously and remained burning for a considerable time. It has been described as a volcanic eruption, and no doubt it corresponds with the popular notion of a volcano. But so far as I can judge it is

the only kind of volcanic action in any way related or associated with petroleum.

The contrast between the bitumen content of the manjac found near San Fernando and that of the "soft" asphalt from the Pitch Lake is very striking.

The principal object I have in view in submitting these notes is to suggest the lines along which any investigation as to the origin of petroleum is likely to be successful. We must satisfy ourselves, in the first place, of the existence of natural substances containing sufficient carbon to account for the large quantities present in the various kinds of carbonaceous deposits and, in the second place, of the existence of natural agencies which under certain conditions convert these substances into peat or coal, and under other conditions into oil or bitumen. I know of no more suitable place than Trinidad for the carrying out of such an investigation. Scientific workers can be assured of reasonably comfortable living conditions. The materials for study are most conveniently situated. There is a laboratory where chemical analyses can easily be arranged for, and there are usually several geologists at work and accumulating data which would be more useful if it became available for oil interests generally. I have heard of a proposal having been made to pool the geological work in Trinidad. I hope it will be carried out. Oil finding is now an urgent problem; and the nation that can evolve the surest and quickest method of locating deposits will reap enormous benefits. It is no longer a problem which should be dependent on individual effort, as it has been mainly in the past; it is now a national problem and our best scientific teams must be sent forth to find the key to it.

There is more data of a chemical nature available at the Trinidad laboratory; and some of it shows, in greater detail, variations in the chemical and physical characters of several of the deposits. Analyses so far made there have been mainly for commercial purposes; there have been great opportunities and temptations for scientific research, but very little spare time owing to a constant plethora of routine work. But the foregoing figures should afford some assistance to geologists in formulating those fascinating generalizations which are both permissible and advantageous in studying the variations in composition and character of the substances found in the earth's crust. Mendeleeff has provided chemists with such a generalization—now known as "the periodic law"—in which the non-metallic and metallic elementary substances are arranged in the order of their atomic weights; something similar will come, in the course of time, from geologists and mineralogists to elucidate their special branches of science. And any revelation as to the origin of petroleum would be a great triumph for

science, and of immense value to recent developments in industry. In no country, in such a small area, can evidence regarding the origin of oil be studied better than in Trinidad. Geologists will find there at least three oil horizons producing oils which show an interesting gradation according to age. The youngest at La Brea is the heaviest and is more highly inspissated; and the oil sand in this horizon contains a larger percentage of "organic matter, not bitumen." The Rio Blanco horizon contains a fairly heavy oil, but not so heavy or sulphurous as the La Brea oil; and with variations in the thickness of oil sands and intervening clays we find alterations in the specific gravities and content of petrol, sulphur and non-volatile residues. From the deeper Galesta horizon we obtain oils—some, such as that found at Lizard Spring, of very high quality—with large percentages of petrol and kerosene, low specific gravities, and so light in colour, owing to natural filtration, that some oil chemists have reported that they were artificially distilled oils. Solid paraffin is found in some of these oils, but the majority of Trinidad oils obtained up to the present have an asphaltic base. Again, the light paraffin oils of the Central Range, if not the oldest oils, have been probably the most deeply buried under impervious sediment; they have a paraffin base, not inspissated, very light in colour and specific gravity, and of the highest standard of quality. It has been stated that some of these oils are obtained from Cretaceous strata; this is possible, and if so they are derived from the Tertiary and filtered in the process.

The lignites of Point Noir on the east coast, and of Rio Negro on the south coast, are at the same horizon as the Rio Blanco oil-bearing group of the western and south-western districts. On the south coast, the transition takes place within a mile. The lignites of the Cunapo "coal field" are at a lower horizon, probably equivalent to the Galeota oil-bearing group which is conspicuous along the Southern Anticline. The lignites in the neighbourhood of Irois and Erin, are on the horizon of the La Brea oil-bearing group. And thus for each main oil-bearing horizon there is a corresponding carbonaceous horizon.

And, to help to link up the two phases, porcellanites derived from bituminous shales are found associated both with lignitic and oil-bearing strata.

There is an abundance of the raw material accumulated mainly in deltaic strata; as these thin out gradually among clays and foraminiferal marls, the oil decreases in quantity and finally disappears; there are the overlying sediments, and especially argillaceous sediments, under which the oil is buried and sealed; and finally, the development of structures favouring the concentration of the oil.

In these notes I have included only the analytical results obtained

previous to 1916 by the staff of the Government laboratory; and, so far as they relate to oils, it is necessary to mention that many of the samples contain large percentages of water. They represent oil-shows on the surface discovered or selected by early inexperienced prospectors, and in such cases do not therefore correctly represent the quality of the oils obtainable from the lower beds. The lighter and more valuable constituents had already evaporated. The records extend over a period of about fifteen years of intermittent, but progressive, development of the oil deposits.

During the same period many geologists have made reports on some of these deposits; only one, so far as I am aware, has had an opportunity of studying and reporting on all of them, and his reports have been published officially. An accumulation of valuable geological information in the former reports is stored away somewhere, and securely sealed under impervious strata; it is only by boring through these that this accumulation, on which brains, money and muscle have been freely spent, can be brought to the surface and its enhanced value utilized in the further development of an industry which means so much to our Empire at the present time and in the immediate future.

DISCUSSION.

The President said those present had had the privilege of listening to a very interesting paper by Professor Carmody, and had been invited by him to visit Trinidad and investigate the problem of the origin of petroleum for themselves. He did not doubt that an hearty welcome—in fact, after what the Professor had said about the climate, he might almost say a warm welcome—would await those who responded to the invitation.

There were several gentlemen present that evening who had had years of experience in Trinidad as Members of the Administrative Council or as officials investigating various geological problems particularly associated with petroleum, and he asked General Brake if he would say a few words in connection with the subject of the lecture.

General Brake said that he felt very diffident, as a mere outsider, in addressing an audience of scientists; but his excuse was that for five years, in the days when the Trinidad oil industry was very young, he was a member of the Council of that colony, and therefore had a very fair knowledge—so far as was possible for an outsider—of the work that Professor Carmody had done in five years out of the twenty-seven which he had spent in the colony, a knowledge which he had gained

partly from the work he had done as Head of the Police. Professor Carmody's work had been of great value to the colony, and later to the Empire; and during the whole time the Professor, he thought he was correct in saying, had been working alone. It was rather an extraordinary thing that in a colony where anyone could see the oil exuding from the ground very little was done to make use of it. The Government was wholly inert to what was obviously so valuable, and the early pioneer work was entrusted entirely to private enterprise. That pioneer work was not altogether successful, because in those days Mr. Cunningham Craig had not come out to investigate the problems or to point out the paths which led to successful oil finding. Before he himself left, however, four men of science arrived—Sir John Cadman, Mr. Cunningham Craig, a Forestry Officer, and a Trigonometrical Surveyor. Until those gentlemen arrived Professor Carmody was the only man of science on the island, unless one counted the doctors, who had quite enough to do. The work that fell to Professor Carmody was extraordinarily heavy; in addition to the ordinary routine work he was in charge of agricultural research and chemical research—the value of which, if not entirely recognized by the cocoa planters, was thoroughly appreciated by the sugar planters, and also undertook the analysis of petroleum, asphalts, etc. The Professor went about his work quietly and unostentatiously; no one knew much about it, and personally he did not think anyone in those days gave him the credit that was his due for half a lifetime spent in the service of the colony.

He felt it a very great pleasure to meet Professor Carmody again after so many years. They were both out of the colony now, and he hoped they would have an opportunity of meeting again. He also wished to say how very much he had been interested in the paper that evening.

Mr. MacCarthy said that as an old colleague of Professor Carmody's he heartily echoed the remarks which General Brake had just made. He agreed with General Brake in thinking that the Professor's services to the colony had not been fully appreciated there, because he was a man whose only amusement was his work. Professor Carmody had certainly earned a rest when he retired from the public service, but he was glad to find that Trinidad had not altogether exhausted him, and that he still had pleasant memories of the island he served so long and so faithfully. It was very difficult, of course, for a non-scientific man to follow the Professor in the more technical parts of his paper, but at the same time he (Mr. MacCarthy) had been interested in the oil industry of Trinidad from its very inception. He had had the good fortune to be present at the sinking of the first well on the island. An incident occurred on that occasion which rather supported what Pro-

fessor Carmody had said as to the value of Trinidad as a centre for the solution of problems connected with oil. He had asked the driller of the well—a Canadian—some questions about his work, and the man told him he had been in almost every part of the world—reciting a long list of countries, north, south, east and west—and he added (speaking through what was known as the Canadian nostril in contradistinction to the American), "All my experience was not worth Hell to me." That was very expressive, and it meant that he was faced by problems which he had met with nowhere else in the world. That illustrated, to some extent, what Professor Carmody had said about the value of Trinidad as an exploration ground for scientists.

General Brake had remarked on the somewhat extraordinary fact that oil was left so long unnoticed in Trinidad. That was a very curious thing, because in half a dozen places one could see the oil running beneath one's feet. For generations the people of Trinidad had watched it and yet made no effort whatever to exploit it. People came from abroad to exploit it, and he had been greatly interested and amused to discover, from recent letters sent to him from the island, that the chief problem now troubling the people of Trinidad was as to how they could get more money out of oil, which meant out of the foreigners who had exploited at enormous expense what they had so long neglected. He supposed that was only human nature, however.

He would conclude by once more expressing his appreciation of the Professor's lecture, and of the pleasure he felt in meeting him again.

Sir John Cadman said the members of the Institution were aware that the subject of the origin of petroleum was a highly controversial one, but he heartily agreed with Professor Carmody that Trinidad was a laboratory, and a great one, for research of the problem. He heartily endorsed what General Brake had said about the great work that Professor Carmody had done in the early days of Trinidad's petroleum career. One often heard tributes paid to the scientists who had worked in that colony, but if one was to ask who really found oil in Trinidad, and who really directed attention to oil questions there, the answer would be that it was the author of the paper to which they had listened that evening. Those who brought the samples to Professor Carmody had in many cases no knowledge of what they consisted of, and it was the Professor who pointed out that the stuff was petroleum. It was Professor Carmody's activity in connection with the work he did in examining those samples which really turned the scientific telescope on to the problem and showed the necessity for an investigation of the island on scientific lines, and it was the support received from their friends General Brake and Mr. MacCarthy—who were both responsible members of the Administration of the colony at the time—which,

brought about progress, which introduced technical officers to Trinidad, and which enabled a systematic and scientific examination of the geological condition of the country to be made. A tribute was due to the author for the persistent way in which he pressed the Government of the day to have the problem investigated on scientific lines, and it was very largely due to Professor Carmody's work that the colony to-day occupied the position it did. The Institution was very fortunate in having the Professor present that evening to give a paper on so important a subject as that with which it dealt. Personally, however, he would like to join issue with the author on certain of the points—he would not call them conclusions—that he had raised. He did not quite agree, for example, with what the author said as to the origin of manjak. That, he thought, was due to slow infiltration, slow deposition, from deep-seated petroleum deposits passing up into fissures in the strata above. He did not think it was due to a rapid irruption such as the author described. His reason for that was that on the walls of those deposits one found a very different structure to that in the inside of the deposit, a definite columnar structure, and the change that had taken place appeared to be due to the very important effect which the clay wall had upon the deposit. However, there were a good many points in the paper which were of considerable importance, the most important of all, in his opinion, being that Trinidad offered splendid facilities as a laboratory for research into the problem of the origin of petroleum, which at the moment had not been solved.

He would like to congratulate Professor Carmody on his youthful appearance. It was almost eighteen years since he first met the Professor in Trinidad, and he did not seem to have altered in the slightest degree. The members were delighted to see him that evening and congratulate him on the most inspiring paper he had brought before them.

Mr. Cunningham Craig said he felt afraid to talk about Trinidad because he knew he would take up too much time, but he would like to make a few remarks on some of the points which Professor Carmody had raised in his paper. First of all, with regard to team work, there were a large number of geologists in Trinidad working for a large number of different companies, and no doubt they discussed things together amongst themselves, but he thought very few of them had the chance of going over the whole country. Each man worked in the particular fields belonging to his company, and had perhaps visited a few of the other fields, but he did not think any of them had had the advantage which had fallen to his lot, of studying the fields before they were known as oil fields at all, of going over practically the whole of them, and of studying them in close liason with such a chemist as Professor Carmody.

He thought the suggestion of team work in Trinidad upon the subject of the origin of petroleum was a very good one. Personally he felt convinced that if all the geologists went out there and studied the island in a broad way the conclusions they would come to would be so definite that there would be very little talk afterwards about the origin of petroleum being a controversial question. He could indicate shortly some of the main features and facts, but was afraid that would take too long, and would therefore only refer to one or two details which Professor Carmody had mentioned. To take, for instance, the question of manjak, he agreed with Sir John Cadman rather than with the author on that subject, about the manjak having come in slowly, because actually in one seam in Trinidad one could see it still coming in, a viscous manjak in the middle of a solid seam. It was not very viscous; one could break it with a sharp tap, but if one laid a block of it on the floor in the course of a few days it would have spread out like a liquid. Another point about manjak which was very interesting was that it was apparently oxidized at ordinary temperatures. He remembered once when he was acting as Inspector of Mines at Trinidad, during the temporary absence of Sir John Cadman, going with Professor Carmody's assistant, Mr. Burt, to take samples of the gas from manjak mines. First of all they shut off the ventilation in one of the galleries for about an hour, and then went down with vacuum bottles and safety lamps. They opened the bottles at selected places, and spent some time making observations, when suddenly he began to feel ill. There was no ventilation, and the air was not very nice, so he went and sat down at the bottom of the shaft and waited for Mr. Burt to follow. Mr. Burt came along shortly, and they were both hoisted up the shaft. Both Mr. Burt and himself were feeling ill, and Mr. Burt asked him to prick his (Mr. Burt's) finger. He did so, and the blood came out very pink in colour, and was later found to be affected by carboxyhæmaglobin. When the samples they had taken were examined in Professor Carmody's laboratory a small percentage of carbon monoxide was found to be present, a direct proof that some oxidation was going on in the manjak.

There were several other points he would like to mention, but perhaps one of the most interesting and amusing was the fact that while oil had been known there so long so few attempts had been made to get it. He believed the first well was a very amateurish affair, put down about seventy years ago by some French people. All except one died of yellow fever, and the survivor ran away, so that was the end of them. The second attempt also was not successful; he saw the remains of it when he was in Trinidad, with a little oil still oozing from it. It was not until the beginning of the present century that real work

began. He well remembered that for years he could not get anybody in Trinidad, not even the officials, to believe in its oil-bearing possibilities. Mr. MacCarthy was one of his first converts; even Sir John Cadman would not believe in it for about a couple of years, and had to be taken into the oil-fields and shown beyond any possible doubt that the land was full of oil. There was a great deal of work going on in Trinidad at the present time, chiefly of the wild-cat type, some of which might have surprising results, but some of which, he was afraid, would prove disappointing. He agreed entirely with Professor Carmody that no better place could be selected for studying some of the most interesting kinds of Tertiary geology that were to be found in the world than Trinidad, and also for studying that wonderfully important subject, the origin of petroleum.

Mr. Gordon Pitt said his only excuse for joining in the discussion was a very great interest in Trinidad and the fact that he had had practical experience in the control of a Trinidad oil-field. In virtue of that experience, and the pleasant and unpleasant memories associated with it, he would like to endorse Professor Carmody's suggestion as to the extremely valuable nature of Trinidad as a field for study with a view to the solution of that highly interesting and vitally important question, the origin of petroleum. His own experience of Trinidad was confined to a much smaller area than Mr. Cunningham Craig's, but it comprised one very interesting feature. At various times during his experience he had had opportunities of investigating the geological conditions in some forty bore holes, and one of the most striking things from the point of view of the man concerned in getting the largest possible quantity of oil from those holes was the extreme difficulty which was experienced in drawing sound deductions from the experience met with in one bore hole which could be used as a guide when dealing with the next. Not only was it very difficult to forecast what would happen every time one began to drill, but also it turned out to be almost equally difficult to forecast even what kind of oil would be obtained when the sands were reached. He had seen two bore holes put down within 400 yards of each other, which were supposed to be laterally placed on the two flanks of the same anticline—he was speaking of a time when the geological information about Trinidad was not so conclusive as it was at the present day—and which produced oil varying in composition to such an extent that in the case of one well the crude oil (after standing, he must admit, in earth reservoirs for two or three days and there losing a proportion of its lighter constituents) gave under distillation 80 per cent boiling under 300° C. and showed practically no asphalt content, whereas in the case of the other well, only 400 yards away, it gave only 15 per cent boiling under 300° C., and

showed over 20 per cent of asphalt. Those were curious figures, and although possibly of no great importance, substantiated Professor Carmody's very interesting and valuable suggestion that within extremely limited areas, and therefore with the fullest opportunities for close observation and comparison, conditions varied so much in Trinidad that one might almost say that there the world's oil conditions, including their very widest variations, were reproduced in miniature. Extremely varied conditions could be studied under extremely easy circumstances.

Having an affection for Trinidad, he would like to tell the members that Professor Carmody might have given rise to rather a mistaken idea about the conditions of life there. It was not so hot as stated. It was true there were all sorts and conditions of climate, and the unfortunate man who was actually in charge of a producing oil-field did not have to bother about whether it was wet or fine; he had got to be out all the time; but, speaking generally, he himself had enjoyed good health all the time he was there. With regard to other amenities, Port of Spain was a charming place, with good hotel accommodation. He mentioned those points in case any members had been so impressed by Professor Carmody's remarks on the geology of the island that they were inclined to go off to Trinidad hot-foot, but might feel deterred by the conditions of life there. He thought everyone who had had experience in Trinidad would endorse in full Professor Carmody's suggestion as to its suitability for research, and he wished to join with other speakers in thanking the Professor for having so clearly pointed out its possibilities in that direction.

Mr. A. Frank Dabell wished to warn the members present that when he left Trinidad three weeks ago it was described as being a place where—

> "Geologists you're sure to meet
> By twos and threes in every street,
> Maintaining with no little heat
> Their various opinions."

The President said the paper had given rise to a very interesting discussion, but had not drawn anyone who had spent years in Trinidad to say very much on the opinions they had formed as to the origin of petroleum, as illuminated by the conditions in that island. Professor Carmody plumped for a vegetable origin. He did not know whether in that respect he was in agreement with the views of the majority. Personally he felt some doubt, after Mr. Pitt's remarks, as to whether Trinidad was really an ideal place for the study of the problem, not on account of the climate or the hotel accommodation (important though these matters were) but because within a very short distance

of each other there were wells which gave such varying products, and that one came across manjak, pitch asphalt, lake asphalt, land asphalt and all the other carbonaceous deposits, one was inclined to wonder whether such over-complexity might not be an extremely bad thing from the point of view of the study of such a very complicated subject as the origin of petroleum.

Professor Carmody, in reply, said his task would be an easy one, because there was very little for him to answer. He thought those present had wisely concluded that it would be better to continue the discussion during the next session, and he promised that if a paper on the origin of petroleum, and the question of the best place in which to study it, was brought up during the forthcoming session he would endeavour to be present and discuss it, whichever view of that origin—animal or vegetable—was taken.

He wished to thank the members very sincerely indeed for their kind remarks about himself. With regard to Trinidad being "as hot as Hell" he had given that as the dictum of an American gentleman, and not as his own opinion; and at any rate he had been there twenty-seven years and had come out of it fairly well. He hoped that Trinidad would be found an ideal place for studying the origin of petroleum, notwithstanding what the President had said, because the variations which were found within so small a compass should be very helpful.

He would like to read a paragraph from Mr. Duckham's letter which he had omitted quoting before: "You speak of the Government laboratory which will be at the service of investigators in Trinidad. I would like to take the opportunity of extending the hospitality of the laboratory at Tabaquite to any *bona fide* investigator of the origin of petroleum, and the imparting to him of any scientific information which our staff may have collected bearing on the subject in question." He thought that was very important. What should be done was to bring the companies together and bring their scientific staffs together. It did not matter in the least whether it was the Government laboratory that was used for the purpose; so long as the chemists and geologists could be brought together in Trinidad there would be a fair chance of getting some idea of the origin of petroleum within a reasonable time, without wasting years in travelling about.

On the motion of the **President** a hearty vote of thanks was accorded to Professor Carmody for his very interesting paper, the vote being carried by acclamation.

The proceedings then terminated.

Contribution from Mr. S. BOWREY.

The survey of the data relating to the oil geology of Trinidad given by the author leaves little room for further contributions except in matters of detail.

One additional fact relating to the Central Oil-field is perhaps worth recording. Not only does Tabaquite produce paraffinous and paraffin-free crudes but the wells from which the former is obtained yield two distinct types of wax. One variety is present in the oil as ordinary amorphous paraffin which by suitable distillation can be refined to paraffin wax melting at 53° C., the other was first noticed as a dry amorphous deposit on the upper part of the well casing. As much as 5 lb. have been scraped from 10 ft. of casing. It resembles chocolate in appearance and fracture, and when freed from impurities by filtration through floridin, corresponds closely to ceresine. The melting point is 93° C.

In order to ascertain whether the ordinary paraffin found in the crude were merely this substance disguised by admixture with oil, it was freed from oil, without resorting to distillation, by repeated fractional precipitation from alcohol-ether. The highest melting point so obtained was only 56° C. Hence it was concluded that the two waxes are distinct varieties.

The manner in which this high melting point wax occurs in the casing suggests that there may be deposits of ozokerite from which gas pressure carries a fine dust up the bore. It would be interesting to know the true explanation of its presence and abnormal melting point.

Contribution from Mr. W. J. REYNOLDS.

I feel constrained to put in a few words in defence of my colleagues in Trinidad, whom the author and a subsequent speaker have to a certain extent unconsciously maligned. The author says quite truly that there are, and have been, a number of geologists in Trinidad working independently for different companies, but it is not quite accurate to say that professional etiquette prevents them collaborating. It would be more precise to say that professional etiquette prevents the geologist making public the results of such collaboration or giving away information thus confidentially obtained even to his own company, though he makes use of it himself in drawing his general conclusions.

The author further says that, so far as he is aware, only one geologist has had an opportunity of studying all the oil deposits of Trinidad,

and Mr. Cunningham Craig, speaking later, said that he had had greater facilities than any other geologist for visiting various parts of the island. Now I landed in Trinidad on the same day that Mr. Cunningham Craig left it on what was, I believe, his last visit. That was in March, 1913, and I have been doing geological work in Trinidad practically ever since. Since that day the colony has been opened up considerably, and great advances have been made in the knowledge of its geology. At first there was a tendency to confine the geologist within the boundaries of his company's concessions, but now the larger companies, at any rate, like the United British, the Leasehold, and the Central, realize that nobody can lay down rules for the geologist except the geologist himself, and they recognize that he is liable to put a blind eye to the telescope when instructions really handicap his work. Besides the greater facilities due to opening up of the colony, the numerous cuttings given by the construction of nearly fifty miles of new railway and some hundreds of miles of new roads, and the increased ease and rapidity of travel, the larger companies have given generous facilities to their geologists in the matter of expenses to an extent which it was utterly impossible for an impecunious Government to give to their official geologist. (The United British alone spent three-quarters of a million pounds in seven years on geological investigation.) Detailed surveys, with contours, have been made in many parts, networks of lines have been cut through the high woods—lines as close, in certain cases, as 66 feet—and money has been liberally expended on shallow and deep excavations where natural exposures were lacking. The erection of permanent camps has enabled the high woods to be penetrated to points which were practically inaccessible, and with a precise knowledge of position which was impossible with a compass traverse. In the alienated lands the oil excitement and the high prices of oil lands have removed the prejudice against the geologist, and Mr. Cunningham Craig's unpleasant experience of the inside of a law court on a charge of trespass has not been repeated by later workers. The negro and Indian five-acre proprietors are unceasing in their requests for examination of their lands, and as for the larger estates the hospitality of Trinidad planters is well known. The planters and estate managers are really apt to hinder the geologist by their hospitable insistence on his staying to lunch or spending the night under their roof, as much as to help him by their readiness to give him the run of their estates, and when absent to offer him the free use of their houses during his stay in their district.

On behalf, therefore, of my colleagues still in Trinidad, it must be admitted that we have had at least equal, and in fact greater, facilities for geological study of all parts of the island, that those facilities have

been zealously taken advantage of by a little band of workers whose keenness in the field is as great as their love for their science, and that considerable advances have been made in Trinidad geology since Mr. Craig's day.

Referring to another point in the paper, I think it is permissible to set the author right about cretaceous oil. No oil is yet known from or in cretaceous strata in Trinidad. At only one point have cretaceous rocks been certainly found, and these are lower cretaceous (Barremian). Their relation to the surrounding strata has not been worked out, and it is even a matter of controversy whether they are actually *in situ*.

Further, with regard to porcellanite, it may be safely stated that in no case is porcellanite found associated with oil-bearing strata. Even in the one area, the La Brea district, where porcellanites and oil-bearing strata occur in geographical proximity, they are not only at different horizons but widely separated stratigraphically. In fact it is safe to tell the owner of the land on which porcellanite outcrops that his chances of oil are very meagre. On the other hand, porcellanite is closely connected with lignite deposits.

To carry the discussion still further, lignites and thin carbonaceous beds are of more or less common occurrence throughout all the coarser Tertiary deposits of Trinidad, and it is therefore difficult to controvert the statement that "for every oil-bearing horizon there is a corresponding carbonaceous horizon." But all the same, such a statement is misleading, since the main deposits of lignite occur in formations younger than the main oil deposits. Moreover, at the base of these formations there is a strong unconformity which brings them into contact with different horizons in the lower beds at different localities.

Contribution from Mr. T. MADGWICK.

Professor Carmody's paper is a welcome contribution to the study of Trinidad oil, particularly the valuable tables embodying his researches on the chemistry of the oils and their weathered products. Would it be possible for him to supplement them with one showing the different hydrocarbon series present in the various oils? We recently had food for serious thought in Mr. Kewley's paper regarding the association of the aromatic series with oils occurring close to coal beds, and one is tempted to ask whether any evidence of a similar association in Trinidad is available. Then, again, the long recognized preponderance of naphthenes in younger oils and members of the paraffin series in those more ancient, the dividing line being somewhere in the older Tertiaries, might well be further demonstrated in Trinidad,

more particularly as Professor Carmody appears to attribute certain occurrences of oil there to rocks of cretaceous age. The point is one of considerable importance as bearing on the origin of oil, for unless we are prepared to accept a different constitution for fats and proteins in early geological times (see Hoefer, *Das Erdoel u.s. Verwandten*, p. 290), or, as Professor Carmody would prefer, perhaps, for cellulose, it is most rational to look for the origin of those oils mainly of the paraffin series as derived from the naphthene oils, time being the important factor. It is precisely that Professor Carmody is advocating Trinidad as a possible field for the study of oil-genesis that I ask these questions.

It is interesting to note further that he inclines to the hypothesis of oil being derived from land vegetation, assigning the major rôle to cellulose, whilst not excluding the other plant-forming substances. He gives no evidence for this preference other than the undoubted vegetable origin of the bulk of coal. In this connection one would like to ask how far his researches into the optically active constituents of these oils have lent weight to this preference? I think few oil men nowadays would assign oil exclusively to either an animal or a vegetable origin, and in the latter case not to land vegetation. The most notable exponent of the cellulose hypothesis was Professor Zuber (*Ztschr. Prakt. Geol.*, 1898), basing his ideas on the work of Leon Popow and Radziszewski, who, to get over the inherent difficulty of the absence of carbon residues in most oilfield facies, which should of course occur in the case of a destructive distillation of cellulose, advocated a purely putrefactive fermentation and conversion of the cellulose into gas (CO_2 and CH_4), and simultaneously the formation of the higher homologues of the hydrocarbon series. Such homologues are unknown in the ordinary fermentation which results in marsh gas, neither do we find the large volumes of CO_2 associated with natural gas which any reaction of this nature would require. It is possible, of course, to argue that it has been removed in water or by absorption of rocks, but some cases might reasonably be expected where the CO_2 was present in quantity. Again, the depth at which such fermentation could go on is probably very shallow—the products would become dissipated, as is seen in ordinary marsh gas evolution.

As regards Professor Carmody's plea for the pooling of geological data accumulated by the various interests now operating in the island, this deserves all the support it can have. I fancy there is now less jealousy in this respect than formerly obtained, and trust that in future the widest publicity be given to all information, even at the risk of a little loss of secrecy which might have a commercial value.

The following Exhibits were shown and referred to during the reading of the paper:—

	Lent by
Lake asphalt (crude)	H. F. Previté, Esq.
Do. (dried or epuré)	
Manjak	
Lake bitumen (refined)	
Fluxing oil	
Glance pitch	The Imperial Institute.
Iron pitch	
Manjak	
Light crude oil (from bulk)	Trinidad Central Oilfields, Ltd. (per A. Duckham, Esq.).
Paraffin wax	
New waxy deposit (crude)	
Do. (highly refined)	
Crude oil (from bulk)	Trinidad Leaseholds, Ltd.
Maps (geological) of the Oil-fields	E. H. Cunningham Craig, Esq.
Do. trigonometrical survey of Trinidad	

The Relation between Alcohol-Water Solubility and Spontaneous Ignition Temperatures.

By W. R. Ormandy and E. C. Craven.

The question of the interrelation of the physical constants of hydrocarbons and derivatives is one of interest to the Institution. The recent work of Moore on "Spontaneous Ignition Temperatures" and of Ricardo on "The Detonation Compressions of various Hydrocarbons" has given us a mass of new data, the interpretation of which, except in a very general way, is as yet not completed.

In the course of some work being carried out on the miscibility of aqueous alcohols of various strengths with hydrocarbons, the suggestion has arisen that there may be a direct relation between these solubilities and the ignition point and toluene numbers of such hydrocarbons. The present note deals with the evidence relating to this suggestion.

In the work referred to above the alcohol strength and temperature have been varied over a wide range so that it was necessary to select some standard alcohol strength and temperature for purposes of comparison. We have taken 92 per cent by weight (94·7 per cent vol.) as the strength of the alcohol, this strength being approximately that of the distilled alcohol of commerce, and the temperature at 15° C. The selection is somewhat arbitrary, but there being no theoretical basis for any particular conditions, it was thought to be as good as any. Solubilities are expressed as the limiting per cent by weight of hydrocarbons in the hydrocarbon alcohol-water mixture.

Relation between Solubility and Spontaneous Ignition Temperature.

A study of Moore's results* shows that—

(1) The ignition points of aromatic hydrocarbons are much higher than those of the aliphatic.

(2) The ignition points decrease with increasing complexity of the molecule.

The solubilities in alcohol follow the same law as is shown by the table below :—

Aromatic hydrocarbons†—	
Benzene . . .	89%
Toluene	88%
Xylol	83%
Aliphatic hydrocarbons—	
n Pentane—miscible all proportions.	
n Hexane . . .	46%
n Heptane . . .	29%
Petrol distillates—	
0·644 S.G. . . .	56%
0·692 S.G. . . .	44%
0·726 S.G. . . .	30%
0·737 S.G. . . .	25%
0·781 S.G. . . .	14%

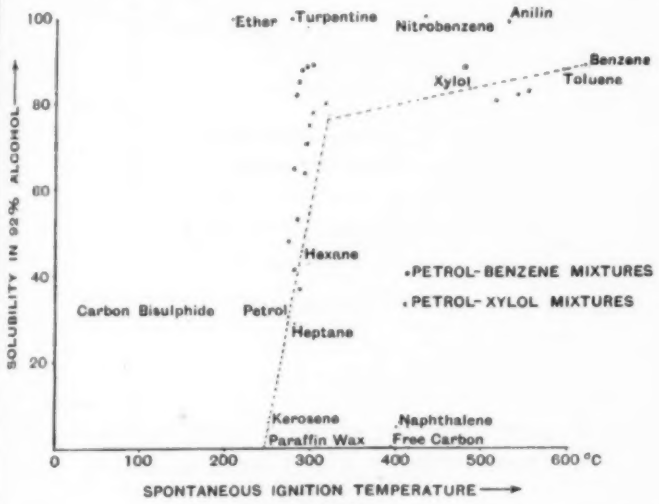
* *Journal VI*, 22, 198.

† Considerable differences have been found in the solubilities of samples from various sources. Mean figures rounded off to nearest whole number have been taken.

Kerosenes—

Borneo	0·853	15%
Mexican	0·784	11%
American	0·801	6%

Based on this idea the solubilities of a number of substances have been plotted against their ignition temperatures in oxygen as determined by Moore, and the results are shown in Graph 1. It will be noticed that the paraffin hydrocarbons fall roughly on a straight line and the aromatic on another, the two lines intersecting about 300° C. Points have been added also for mixtures of xylol, petrol, and benzene



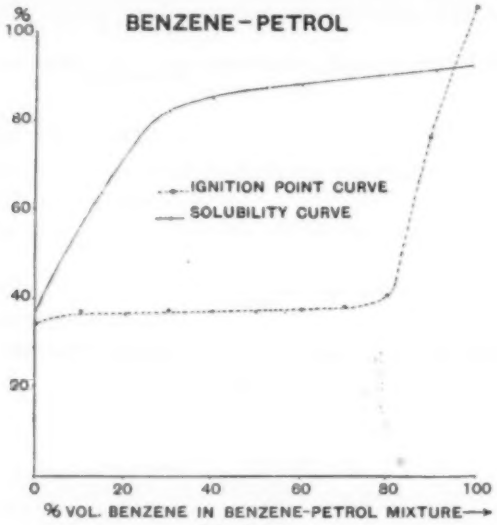
Graph I.

and petrol in 10 per cent* steps. These also appear to follow the general trend of the other values. In regard to all these values, therefore, some sort of relation would appear to be indicated. Turning however to other bodies, a great many exceptions to this relation can be found. Many substances appear to mix in all proportions with the 92 per cent of alcohol at 15° C. Points are shown for ether, turpentine, nitrobenzene and anilin, bodies which may be said to be of high solubility, but having widely differing ignition points. Carbon disulphide provides an example of a body of moderate solubility but with a very low ignition point.

* Calc. from results at 20° C.

It is perhaps scarcely fair to consider solid bodies in this connection, but as the ignition points are available naphthalene and free carbon may be mentioned. The solubility of the former body is about 5 per cent (Bachi. B12. 1978), yet it possesses an ignition point (402° C.) far above that of a paraffin of the same solubility. In the case of "free carbon from tar" we have a body which is practically insoluble in alcohol but which has a high ignition point.

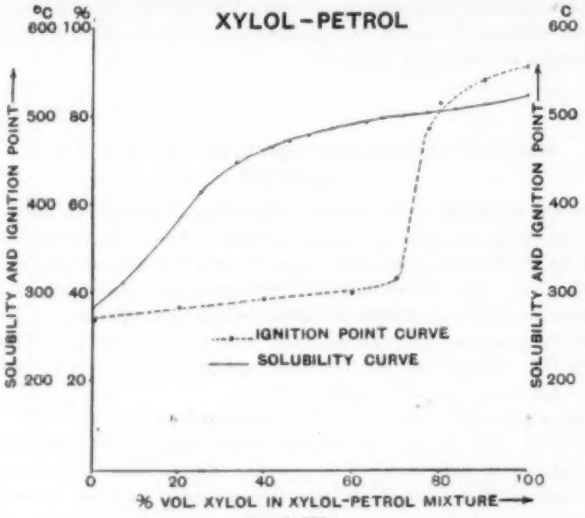
In order to test further the question of the solubility—ignition temperature relations—the alcohol solubility of some of the binary



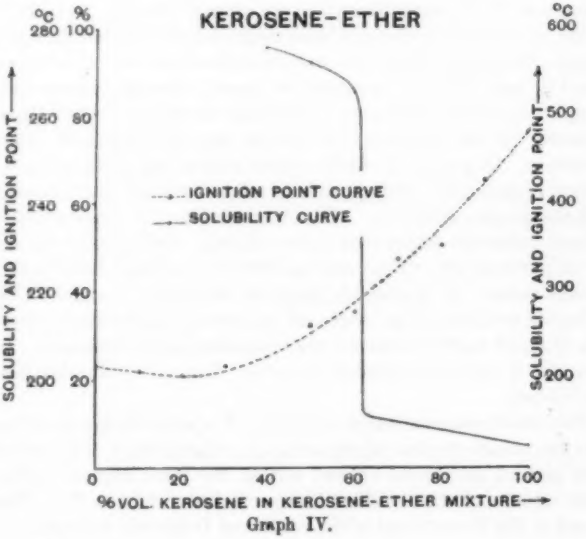
Graph II.

mixtures* tested by Moore (J.G. 22. 201) was determined, and the curve of solubility variation plotted on the same graph as the ignition point curve. The results are shown in Graphs II–V. The alcohol solubilities in this case are given by the volume per cent of hydrocarbons in the mixture with aqueous alcohol at 20° C. It will be seen that in the case of the benzene—petrol and xylol—petrol mixtures although the overall slopes of the curves have been made roughly equal the rates of variation of the slopes of the curves are very different, i.e. where the solubility rises rapidly the ignition points rise slowly and vice versa. In the case of the ether mixture the results are absolutely against the solubility-ignition point relationship, a high solubility corresponding

* See Appendix for figures.



Graph III.



Graph IV.

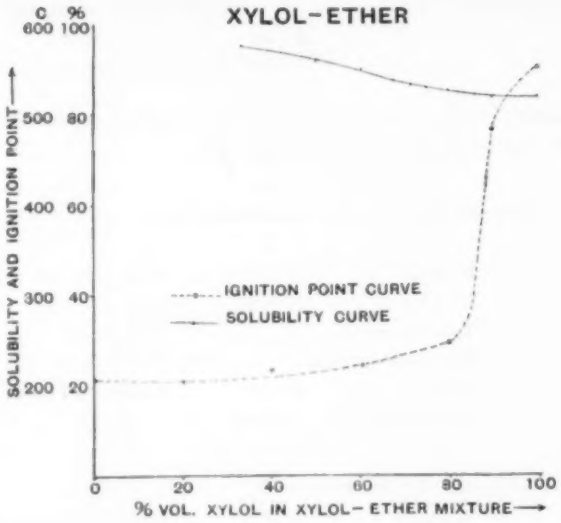
to a low ignition point and vice versa. Considering the evidence as a whole, therefore, it may be said that no direct relation between the two properties has yet been shown.

Relation between Solubility and Toluene Value (Ricardo).

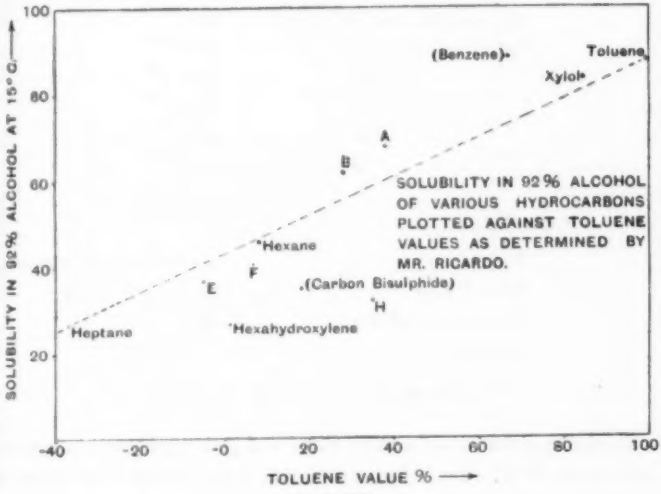
By the kindness of the Asiatic Petroleum Company we have been able to obtain samples of various petrols and other hydrocarbons as used by Mr. Ricardo in his work reported on in *The Automobile Engineer*, April, 1921. As a standard for comparing the maximum effective compression ratio (thus also the indicated thermal efficiency and mean effective pressure) for various fuels toluene is given the arbitrary value 100. Other fuels can be tested against toluene, and a "toluene value per cent" can be assigned to them.

The samples received comprising petroleum spirits "A," "B," "E," "F" and "H," hexane and heptane, were examined for solubility in alcohol over a wide range of temperature and alcohol strength, and it was noticed that a rough correspondence existed between the order of solubilities and the toluene values as recorded in Ricardo's report. Taking as before the per cent by weight of hydrocarbon in the saturated mixture at 15° C. using 92 per cent wt. strength alcohol, the solubilities of the various hydrocarbons have been plotted against their toluene (values), Graph VI. It will be noticed that some two-thirds of the samples tested lie very close to a straight line passing through toluene and heptane, whilst of two of the points off the line the toluene values have been obtained by an exterpolation process and are therefore somewhat uncertain. In general it would appear that as far as data is available a very considerable correspondence exists between the toluene value and the alcohol solubility. The chief exception is ether which has a toluene value of −64 per cent (exterpolated). Other bodies miscible in all proportions with 92 per cent alcohol, e.g. acetone, have fairly high toluene values. It is probable, however, that tests on a greater variety of liquids would show an increased proportion of divergences from any rule of direct relation between the properties under discussion. In this case also it may be concluded, therefore, that no relationship has been established.

This short research forms a portion of a much larger investigation into the whole question of the solubility relationships of hydrocarbons with alcohol and water carried out at the joint request and at the joint expense of the Distillers Company, Ltd., and the Fuel Research Board of the Department of Scientific and Industrial Research.



Graph V.



Graph VI.

APPENDIX.

Solubility in 92 per cent alcohol at 15° C. of bodies mentioned in text in per cent by weight in saturated mixture:—

Aromatic Hydrocarbons and Derivatives—

	%
Benzene	89·2
Toluene	88·0
Xylol (comml)	83·4
Hexahydroxylene	26·4
Anilin	miscible all proportions.
Nitrobenzene	„ „

Aliphatic hydrocarbons—

Pentane	miscible all proportions.
Hexane	46·4 (mean 3 samples).
Heptane	28·5 „ „
Heptane (as used Ricardo)	26·4
Petrol spirits—"A"	68·2
"B"	62·1
"E"	37·2
"F"	40·9
"H"	31·8

Other bodies—

Turpentine	miscible all proportions.
Ether (·730)	„ „
Carbon bisulphide	34·6

Solubility of Binary Mixtures.

Solubility given in per cent by volume of hydrocarbons in saturated mixture at 20° C. The petrol, ether, etc., were selected so as to be as nearly as possible of the same kind as used by Moore.

Benzene—Petrol Mixture—

% vol Benzene.	% vol Petrol.	Solubility.
100	0	93·1
80	20	90·3
60	40	88·3
50	50	87·3
40	60	84·9
30	70	81·8
15	85	63·4
0	100	37·3

Xylol—Petrol Mixture—

% vol Xylol.	% vol Petrol.	Solubility.
300	0	84·6
90	10	82·3
83·3	16·7	81·4
76·9	23·1	80·9
71·4	28·6	80·2
62·5	37·5	79·0
55·6	44·4	77·6
50	50	76·2
45·4	54·6	74·8
41·7	58·3	73·7
33·3	66·7	70·0
25	75	63·1
7·7	92·3	42·5
0	100	37·3

Ether—Xylol Mixture—

% vol Xylol.	% vol Ether.	Solubility.
33·3	66·7	95·8
50	50	93·0
60	40	91·2
66·7	33·3	88·2
71·4	28·6	87·0

Ether—Xylol Mixture—

% vol Xlyol.	% vol Black.	Solubility.
75	25	86·8
80	20	86·2
86	14	84·6
90	10	84·3
100	0	84·6

Ether—Kerosene Mixture—

% vol Kerosene.	% vol Ether.	Solubility.
40	60	96·1
50	50	91·9
60	40	85·0
61·9	38·1	13·2
67	33	12·0
100	0	6·0

Some Notes on the Estimation of Sulphur and Chlorine by the Lamp Method.

By S. Bowman, A.I.C.

Although the Calorimetric Bomb is frequently used and generally considered the most satisfactory method for the determination of sulphur in petroleum products, this view is more probably due to the imperfections of alternative methods rather than to the excellence of the bomb for analytical work.

Originally devised for the determination of a physical constant it is doubtful whether the constructive details of the bomb are conducive to that degree of accuracy necessary for quantitative analytical work where minute quantities of an element are under examination.

For example, numerous experiments have shown that when an estimation of sulphur in a product such as refined benzine is made in a bomb which has been previously used for a fuel oil or other sulphurous oil, the results are always high and repeat tests inconsistent. The bomb may have been thoroughly washed out after the previous experiment, but owing to the construction a certain amount of H_2SO_4 still

remains in the valve fittings and can only be removed by complete dismantling—a troublesome operation. Further, the lead washer is a source of trouble, holding sulphur with such tenacity that repeated washings continue to reveal traces of that element.

In order then to get reliable results with the bomb it would appear to be necessary to have a separate bomb for each class of product dealt with, at of course an almost prohibitive cost.

Other drawbacks to the bomb method are the small quantity of material permissible and the corresponding increase in the percentage error when dealing with products of low sulphur content; and also the necessity of always having a ready supply of oxygen under pressure.

From the above considerations it would appear that an alternative method to the bomb is most desirable, and as such the Lamp Method suggests itself as the most practical one, although in all its modifications is not entirely free from certain disadvantages, the chief being the absorption of sulphur compounds by the cotton wick.

This absorption has been frequently commented upon by different workers and has been shown to take place with all petroleum products, from the lightest to the heaviest fractions. No amount of rinsing and burning of the solvent used appears to remove the sulphur so absorbed, and from experiments made by the writer the amount is much higher than was at first thought possible.

Experiments were therefore made with a view to eliminate this defect, and the following substitutes for cotton wick were tried :—

1. A strip of filter paper rolled into a spill was found to have a fairly good capillarity, but attempts to gradually withdraw the spill and burn it at the top of the holder proved unsuccessful on account of the paper becoming firmly adhered during the experiment.

2. Asbestos fibres were used with a view to subsequent ignition, but after this treatment they became too friable and possessed a low capillarity.

3. Fine glass capillaries were found to have insufficient capillarity at ordinary pressures.

4. Similarly fine mesh gauze had the same defect.

From these experiments it is clear that in order to get the oil to burn with a satisfactory flame, cotton wick must be used, but it was found that after the usual burning operation in the lamp had been completed it was possible to extract the wick and burn it in a short length of combustion tubing with the aid of a slow current of air, scrubbing the gases of combustion in the same vessels used for the experiment.

In this way a short length of wick (4") is completely burned to a small amount of mineral ash weighing about 2 milligrammes, the operation only taking five minutes.

With regard to the sulphur absorbed by the wick it is interesting to note here that some of this sulphur still remains behind in the ash in the form of sulphate, the cotton having been ascertained beforehand to be quite free from this element.

This will be readily understood when it is considered that the ash of the cotton is alkaline in reaction, and combination is likely to take place before the sulphur is completely volatilized.

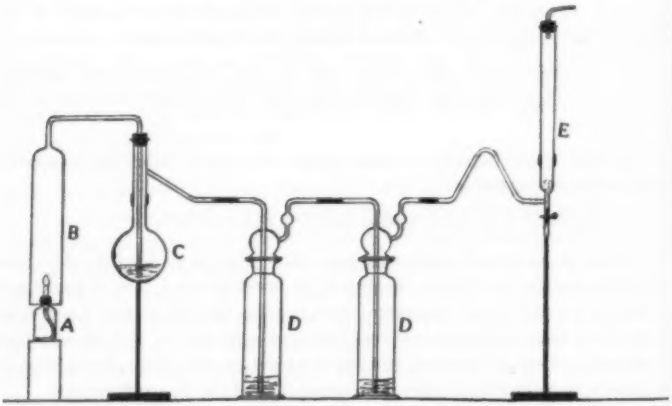
It is therefore necessary that after burning the wick in the manner described the ash itself should be brushed out and added to the liquid from the scrubbing vessels. The ash is entirely soluble when the liquid is acidified in the ordinary course of procedure, and any sulphate present is precipitated in bulk.

The following figures show the distribution of sulphur throughout a typical determination on unrefined kerosene:

S. volatilized during burning of the oil = ·175%
S. volatilized during burning of the wick = ·005%
S. remaining in the ash of the wick = ·004%

Total sulphur = ·184%

The apparatus employed in these experiments is that suggested by Dunstan and Thole, and has the advantage of simplicity and being composed of material available in any well-equipped laboratory.



A. 1 oz. glass bottle fitted with grooved cork and short length of silica tubing for holding the wick.

B. Glass chimney $7'' \times 1\frac{1}{2}''$.

C. 50 cc. distillation flask.

D. 150 cc. Dreschel wash bottles.

E. Trap vessel.

C, D, and E are each charged with about 1 cc. Na_4CO_3 sol. + 25 cc. H_2O.

Chemicals required :

10% sol. Na_4CO_3 for charging absorbers.

Amyl Acetate for dilution.

Sod. Peroxide.

Con. Nitric Acid.

Saturated sol. Barium Nitrate.

$AgNO_3$.

$\frac{N}{100}$ = HCl sol.

All the above chemicals to be free from sulphur and chlorine compounds.

A convenient source of suction for use with this apparatus is a small motor driven ($\frac{1}{4}$ h.p.) Lennox Blower, and will supply sufficient draught to run six sets simultaneously, but whatever source of suction is used it must be of a steady character.

Needless to say the atmosphere must be reasonably free from sulphurous vapours, otherwise it will be necessary to enclose the lamp and chimney in a hood and purify the ingoing air.

Method :

For petrol, white spirit and kerosene, measure 5 cc. into the lamp by means of an accurate pipette, noting the sp. gr. at the time. (Dilution with a solvent is unnecessary.)

For gas oil, lub. oils, fuel oils and residues, weigh direct into the lamp about 0·5 gms. and dilute with 10 cc. amyl acetate, gently shaking until completely dissolved.

Replace the wick holder fitted with 4″ of cotton wick consisting of about 20 strands, and light the lamp, adjusting the draught to produce a clear non-smoking flame. An excessive current of air should be avoided, otherwise there is some risk of incomplete absorption of the oxides of sulphur formed.

The lamp is allowed to burn to dryness and then washed twice with a few cc. of amyl acetate, burning to dryness after each wash.

The wick is now extracted from the holder, doubled and inserted into a 6" length of combustion tubing connected up to the wash bottles in place of the distillation flask. The empty part of the combustion tubing is then heated by means of a Bunsen burner, gradually moving the flame towards the wick, which commences to glow and burns to a white ash. If conducted in this manner the formation of tarry matter is reduced to a minimum and a clean ash left behind.

The absorbing vessels and all connections, including the chimney, are now thoroughly washed out into a 400 cc. beaker, together with the ash from the wick, about 1 gm. of Na_2O_2 added and the liquid brought to boil. Acidify with HNO_3, keeping the beaker covered, and precipitate with $Ba(NO_3)_2$ solution and finally allow to boil gently for thirty minutes.

After standing overnight the $BaSO_4$ is filtered on a 9 cm. paper previously washed free from chlorides, washed, ignited, treated with one drop of 20% H_2SO_4—HNO_3, ignited again and weighed.

The Cl is determined in the filtrate by adding a few cc. of $AgNO_3$ and comparing the turbidity with a blank solution of similar volume contained in a beaker of the same size and shape, containing an equal amount of the reagents used and to which is added $AgNO_3$ and N/100 HCl. Ten minutes should be allowed for the turbidity to develop to its full extent and the beakers should be protected from light.

The accuracy of this method has been carefully checked, using a standard solution of diethyl sulphide in alcohol and is believed to be an improvement on the older methods, inasmuch as the total sulphur contained in all classes of petroleum products from light benzine to heavy fuel oil can be determined.

Royal Aircraft Establishment Report, No. H.G. 410.

Report on Methods of Determining the Calorific Values of Certain Unsaturated Hydrocarbons

SUMMARY.

A series of investigations have been carried out on methods of determining the calorific values of the mixture of unsaturated hydrocarbons which composes the "Special Motor Fuel (F.7)" from Birmingham. This fuel shows a great tendency to detonate when burnt in the Bomb Calorimeter and also to escape complete combustion. Experiments were made to overcome these difficulties; the most successful method consisted in damping down the oxygen with varying quantities of CO_2. The best results were obtained by using about 20% of the latter gas.

Results were finally derived which did not differ from one another by more than 1%; the mean of these figures was therefore adopted.

The calorific value of the fuel is slightly lower than that found for Shell A (from Sumatra).

Materials.

In July, 1918, a sample of "Special Motor Fuel (F.7)" was received from Birmingham. This fuel had been obtained by the cracking of heavy oils and consisted largely of hydrocarbons of the olefine series. Two further consignments were received in January and February of the current year.

An attempt was made to determine the calorific value of the first consignment in the bomb calorimeter in the same way as that of petrols is determined; the material, however, showed a strong tendency to detonate when fired in the bomb, and even when this did not occur the residual gas always smelt of the unburnt hydrocarbon; the results were therefore questionable.

Various experiments have therefore been made to avoid (*a*) detonations, (*b*) incomplete combustion. The materials used for these were amylene fractions obtained by distillation of the fuels.

Experiments with the Amylene Fraction Obtained from the First Consignment (July, 1918) Boiling Range 30°–35° C.

1. *Sealed Bulb Method.*

This method was the same as that used for petrols with the exception that the bulb was not broken before combustion.

No explosions occurred, but the results obtained were very diverse so that combustion could not always have been complete.

2. *Xylol Method.*

The amylene was mixed with an equal quantity of xylol and the resulting mixture burnt in the usual way.

The two results obtained were very low, although no explosion was detected.

3. *Benzol Method.*

Mixtures of amylenes and benzol were made, the proportion of amylene varying from 50% to 10%.

A violent explosion occurred with the 50% mixture but with none of the others; in all cases, however, the residual gas smelt more or less strongly of the unburnt hydrocarbon and the results were very divergent.

RESULTS.

Method.	Calorific Value in Cal/gm.	Mean Result.
1. *Sealed Bulb* . . .	11·910 11·207 10·575	11·067
2. 50% *Xylol* . . .	10·973 10·758	10·866
3. *Benzol and Amylene*—		
33% Amylene . .	11·498 11·049	11·273
25% „ . .	11·622 11·249 11·207	11·326
20% „ . .	11·458 11·084	11·271
10% „ . .	11·251	11·251

From these results it appears that no satisfactory method of determining the calorific value of this fraction had been found.

Since all the material had been used up in the foregoing experiments the next series was performed with the amylene fraction from a later consignment (January, 1919) with a boiling range of 25°–40° C.

4. CO_2 *Method.*

The oxygen was damped down with varying quantities of CO_2. The latter was introduced into the bomb from a cylinder of the gas until the required pressure was obtained, oxygen was then added until the usual pressure of 500 lbs./sq. inch was registered.

No explosions occurred but the residual gas again always smelt more or less strongly of the hydrocarbon. The results, however, were much more uniform than those previously obtained.

% CO_2.	Cal/gm.
0	11·348 here a slight explosion was heard.
1	11·285
10	11·342
20	11·429
35	11·371
50	11·296
Mean	11·345

Original Fuel.

Experiments were now made with the January and February consignments of the original fuels with the following results :—

Fuel.	% CO_2.	Cal/gm.		
(*a*) Jan. Consignment	0	11·156	Slight C. deposit.	Smell of unburnt hydrocarbon.
(*b*) „ „	0	11·209	Large „ „	Less smell.
(*c*) „ „	20	11·236	No „ „	Strong smell.
Mean result		11·200		
(*d*) Feb. Consignment	20	11·177	No „ „	„ „
(*e*) „ „	20	11·236	Large Explosion.	C. deposit. Strong smell.
Mean result		11·206		

From these results it appears that the presence of about 20% CO_2 does tend to reduce the violence of the explosion. The smell of unburnt hydrocarbon in the residual gas shows, however, that the method is not entirely satisfactory, but as the results do not vary from one another by more than 1% the mean values have been adopted.

The detonation which occurred in experiment (*e*) was probably due to the temperature being higher than the normal. Similar results have been obtained in attempting to burn petrols in hot weather. This

suggests that it may be possible to avoid detonations altogether by sufficiently reducing the temperature.

Net Values.

Combustion analyses as before were carried out with the three samples of fuel. From the hydrogen results so obtained a correction was made which included (*a*) the latent heat of condensation of the steam and (*b*) the fall in temperature of the water from 100° C. to 15° C.

Results.	Sp. Gr. 15°/4°C.	% H.	Cal/gm. Gross.	Cal/gm. Net.	B. Th. U/lb. Gross.	B. Th. U/lb. Net.
July, 1918, Consignment	·707	13·8	11,264	10,490	20,277	18,882
Jan. 1919 "	·701	13·6	11,200	10,441	20,160	18,797
Feb. " "	·692	13·5	11,206	10,450	20,170	18,812
Shell "A" (from Sumatra)	·720	14·7	11,309	10,485	20,352	18,871

Royal Aircraft Establishment Report, No. H. 861.

Report on the Calorific Values of Petrols and of Petrol Fractions.

SUMMARY.

(*a*) Introductory.

A series of investigations have been carried out to gain information upon the relative calorific values of motor fuels and to find a relationship between these values and other physical and chemical properties.

(*b*) Range of the Investigation.

The following fuels have been employed as subjects for investigation :—

Shell "A," aviation spirit from Sumatra, as used by R.F.C. until July, 1918.

Two consignments of American petrol *ex* s.s. "British Isles" and s.s. "British Light."

A sample of petrol from Sumatra for experimental purposes (F.1).

A sample of petrol from Borneo for experimental purposes (F.3).

These last two samples were prepared to meet the requirements of the French "Extra-aviation" specification.

The calorific values of a number of liquids which had been obtained by the fractional distillation of petrols, have also been determined; these liquids were obtained by the fractional distillation of "British Isles" petrol (for the lower boiling portions) and of motor transport spirit (for the higher boiling fractions). In addition, experiments were performed on benzol, toluol and xylol.

The gross calorific values have been determined by means of a Mahler-Cook bomb calorimeter. In addition, a combustion analysis of each fuel has been carried out. In this way, the percentage hydrogen has been determined for each sample, and from this and from the gross calorific value the net calorific value has been calculated.

The fractionation of the "British Isles" petrol was carried out by means of a 5′ Darier column connected with a Liebig's condenser: the distillate was collected at the rate of about one drop per second. The receiver was changed for about every 10° C. rise in temperature, so that the boiling-points of the fractions corresponded roughly with those of the lower saturated paraffins (pentane to octane). In the fractionation of the motor transport spirit, the Darier column was replaced by a 12-pear still head.

The percentage of aromatic compounds in each petrol sample was determined by critical solution temperature method and the olefine content by the bromine absorption method—percentage of saturated paraffins being found by difference.

The specific gravity of the liquids was found by means of specific gravity bottles, and has been reduced in each case to 15°/4° C.

(*c*) Conclusions.

With regard to the petrol fractions, it has been shown that in ascending the scale from pentane to octane, there is a fall in calorific value of about 3%.

The calorific values of the petrol samples do not vary from each other by much more than 1%.

As a general rule the calorific value is found to increase with decreased specific gravity, and to decrease with an increase in the percentage of aromatic compounds present.

The Combustion of Petrol in the Bomb Calorimeter.

The general method of carrying out the combustion is as follows:—

A small amount of the liquid is weighed in a glass bulb with a fine

capillary neck; the platinum crucible is provided with a thin layer of asbestos and placed securely in its support, the fuse, of iron wire, is fastened to the terminals and the electrical connections are tested by means of a small 2-volt lamp. When all is in readiness the sealed end of the neck of the bulb is broken off and the latter is at once put in the crucible in such a way that the fuse touches the glass; the small sealed end is also dropped in, and the lid of the bomb is then quickly screwed down into the body. Oxygen is then admitted slowly through the needle valve until the pressure rises to 500 lbs./sq. in.

The same amount of water is put into the calorimeter for each combustion, and whenever possible the initial temperature is so adjusted that it is slightly above that of the water in the outer jacket.

Insulated wires are fastened to the terminals of the bomb and the latter is lowered into the calorimeter, the lid is put on and the thermometers, etc., are put into position.

Preliminary temperature readings from the Beckmann thermometer are taken at half-minute intervals for four minutes, the fuse is then fired by connecting the wires to accumulators which give an E.M.F. of eight volts, the temperature rapidly rises and reaches a maximum about five minutes after the fuse is fired. Half-minute temperature readings are taken during this time and for another six minutes in order to give the rate of cooling after combustion. The water in the calorimeter is constantly stirred by the hand stirrer throughout the experiment.

Considerable difficulty in burning the petrol successfully was at first experienced. In the majority of the early experiments detonations occurred which were so violent that the crucible was flung from its support and the enamel lining of the bomb was damaged, at the same time the combustion was incomplete and carbon was deposited on the sides of the bomb.

These detonations were found to be less frequent if only a small vapour bubble were left in the bulb, and when this was completely eliminated they became of rare occurrence. In the case of certain mixtures of olefines, however, the trouble recurred even in cases where no vapour bubble was visible, so that accurate calorific values have not yet been obtained for these compounds.

It was found from experience that the following conditions are necessary to ensure successful results:—

1. The small glass bulb must be free from vapour bubbles.

2. The walls of the bulb must be as thin as possible, otherwise the glass is not completely fused and the petrol cannot escape.

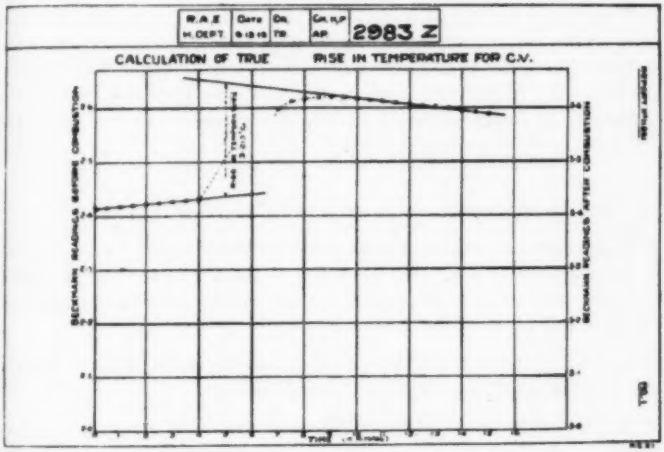
3. The fuse must be in actual contact with the glass.

Combustions of petrol in very hot weather should be avoided, as explosions readily occur.

The weight of petrol burnt varied from ·5–1 gm., giving temperature rises of about 1·5–3° C.

Calculation of Results.

The readings of the Beckmann thermometer are plotted against time as shown in Fig. 1. Those before and after the actual combustion are on straight lines. The distances apart on the temperature scale, of these lines produced at the time of most rapid rise of tempera-



ture, is taken as the true rise brought about by combustion. Thus, in the case illustrated, the temperature rose from 2·414° to 2·432° during the four minutes before ignition. As soon as the fuse was fired the temperature rose rapidly, as shown by the dotted line. The curve on the right represents the changes towards the end of the experiment, a maximum of 5·020 was reached 4½ minutes after ignition, this was maintained for 1½ minutes, after which the temperature fell uniformly. The time of most rapid rise was taken as 1 minute after ignition, which gives a true rise of temperature of 3·213°. As the two straight lines are only slightly inclined to each other, the precise position in time of the intercept is not important, a variation of half a minute being well within the accuracy expected from the bomb.

A series of preliminary experiments with pure substances of known calorific value had previously been performed whereby a figure was

obtained which represented the amount of heat necessary to raise the temperature of the water in the calorimeter and of the bomb, etc., by 1° C. From this figure and from the increase in temperature found for a given weight of petrol, the calorific value of the sample can be found. A correction is made for the heat given out by the fuse.

Combustion of Benzol, Toluol and Xylol.

Benzol, having a boiling range of 80°–83° C., was used in these experiments. The boiling range of the toluol was 108°–110° and that of the xylol was 136°–142° C.

The benzol and toluol were burnt in the bomb in exactly the same way as the petrols, but some difficulty was experienced in starting the combustion of the xylol; this was overcome by embedding the bulb in about ·5 gm. of pure cane sugar, the iron wire then first ignited the sugar which in turn ignited the xylol. A correction was applied for the calorific value of the sugar used.

Determination of the net Calorific Values.

The results obtained by means of the bomb calorimeter give only the gross calorific values. In order to obtain the net calorific values (i.e. the amount of heat available in the engine) a correction must be made which involves two factors:—

1. The latent heat of condensation of the water formed by the combustion of the hydrogen in the hydrocarbon.

2. The fall in temperature of this water from 100° C. (in the engine) to 15° C. (in the bomb).

A series of combustions have therefore been carried out to estimate the percentage hydrogen in each liquid which was burnt in the bomb.

The Combustion Apparatus.

The combustions were carried out by the usual CuO method. The H_2O being absorbed by strong H_2SO_4 and the CO_2 by soda lime. Air was passed through the tube during the combustion and was followed by a stream of oxygen to burn off any carbon deposit which might have been formed in the tube.

Method of Carrying out the Combustion.

Blank experiments were first performed to make sure that the

apparatus was in working order. The petrol combustions were then carried out as follows :—

The tube was heated for about twenty minutes with air passing through to drive off all moisture ; all the burners except those under the CuO were then extinguished meanwhile, a small amount of petrol (about ·2 gm.) was weighed in a small glass bulb ; in filling the latter care was taken to leave a vapour bubble as otherwise, when heated in the tube, the petrol is expelled with violence. When the back part of the combustion tube was only just warm the absorbing tubes were attached to the front end and the apparatus was then ready for the insertion of the petrol bulb ; the sealed end of the neck of the latter was broken off and both pieces were quickly put into a porcelain boat containing a small plug of asbestos. The boat was then put into the combustion tube as quickly as possible and was followed by a long roll of CuO gauze. One or two burners at the back of the tube were then ignited. Throughout the combustion air passed through the tube at the rate of about ·2 c.c. per second. The temperature of the part of the tube containing the boat was kept low enough to enable the tube to be touched by the hand.

The petrol gradually soaked into the asbestos and was then vapourized and carried over the CuO (which was maintained at a red heat) and so oxidized. When most of the petrol had been burnt, more burners were gradually lighted until the tube was heated throughout its length. Oxygen was then passed through for about five minutes to ensure complete combustion. Air was then again passed through for ten minutes to sweep out the oxygen.

The time taken over the combustions varied, the average was about 1½ hours.

Application of the Results of the Combustion.

From the percentage hydrogen found for each sample of fuel the weight of water formed per gram of liquid could be determined. This figure was then multiplied by 622, which represents the latent heat of condensation of water (537 cal./gm.) plus a fall in temperature of 85° C. The results, when deducted from the gross calorific values given by the bomb, gave the net calorific values.

Degree of Accuracy.

The gross and net results are estimated to have an accuracy of within 1%.

RESULT.

Fraction.		Sp. gr. 15½° C	% H.	Cal/gm.		B. Th. U/lb.		Some Published Values, net Calc. Val. Cal/gm.	
				Gross.	Net.	Gross.	Net.	Gross.	Net.
	"British Light"	·696	15·51	11,520	10,652	20,736	19,178		
	"British Isles"	·719	15·07	11,335	10,421	20,403	18,887		
	"Shell A"	·720	14·72	11,300	10,485	20,352	18,871	11,252	10,400
	Sumatra	·731	14·87	11,240	10,407	20,233	18,737		
	Borneo	·740	14·01	11,161	10,377	20,087	18,678		
	Decane Fraction, 168°–178°	—	14·33	11,249	10,447	20,244	18,803		
From	Interte ,, 153°–168°	·775	14·36	11,233	10,420	20,221	18,777		
Motor	Nonane ,, 148°–153°	—	14·65	11,263	10,443	20,273	18,799		
Transport	Interte ,, 138°–148°	·763	14·42	11,355	10,549	20,441	18,990		
Spirit	Interte ,, 128°–138°	·753	14·90	11,327	10,493	20,389	18,890		
	N.-Octane ,, 120°–125°	·745	14·99	11,332	10,493	20,394	18,886		
	Iso Octane ,, 115°–120°	—	15·22	11,347	10,495	20,421	18,890		
	Toluol ,, 100°–115°	·745	14·64	11,348	10,528	20,427	18,954		
From	N. Heptane ,, 95°–100°	·733	14·87	11,391	10,558	20,505	19,009	11,375	
British	Iso Heptane ,, 8 °– 92°	—	15·17	11,487	10,638	20,678	19,152		
Isles	Hexanethylene Benzol, etc., 72°–85°	·734	14·70	11,332	10,509	20,398	19,919		
Petrol.	N. Hexane Fraction 67°–72°	—	15·16	11,516	10,667	20,730	19,178		
	Hexane Middle Fraction 65°–67°	·699	15·56	11,503	10,632	20,704	19,138	11,525	10,636
	Iso Hexane ,, 60°–65°	—	15·53	11,572	10,703	20,830	19,268		
	N. Pentane ,, 35°–40°	·667	16·53	11,698	10,773	21,057	19,394	11,625	
From Purfleet.	Iso Pentane ,, about 30°	—	16·53	11,673	10,748	21,013	19,350		
	Benzol 80°–83°	·883	7·05	10,065	9,620	18,117	17,317	10,070	9,650
	Toluol 108°–110°	·868	9·06	10,257	9,750	18,462	17,552	10,160	
	Xylol 136°–142°	·862	10·00	10,379	9,819	18,682	17,676	10,254	

The iso-pentane result was obtained from a sample which consisted chiefly of this hydrocarbon mixed with small quantities of

TABLE TO SHOW THE COMPARISON OF CALORIFIC VALUE WITH OTHER PROPERTIES.

Petrol.	Boiling Range.		B. Th. U/lb.	% H.	% C.	Sp. Gr.	% Aromatics.	% Olefines.	% Naphtenes.	% Paraffin.
	% below 20° C.	% above 150° C.								
British Light"	4	2	19,176	15·51	84·55	·696	2·5	1·0	20	76
British Isles"	5	2·5	18,887	15·07	84·53	·719	4·5	1·25	22	72
Shell A" . .	4	2	18,871	14·72	86·10	·720	6·7	trace	35	58·0
matra . . .	5	2·5	18,737	14·87	85·16	·731	15·5	trace	25·5	59
rneo . . .	4	trace	18,678	14·01	86·32	·740	23·0	0·1	27	30

The iso-pentane result was obtained from a sample which consisted chiefly of this hydrocarbon mixed with small quantities of

10,254
17,676
18,682
9,819
10,379

CONCLUSION.

With regard to the petrol fractions, in ascending the scale from pentane to octane there is a fall in calorific value of about 3%. This is to be expected, as the lower boiling fractions contain a higher proportion of hydrogen to carbon.

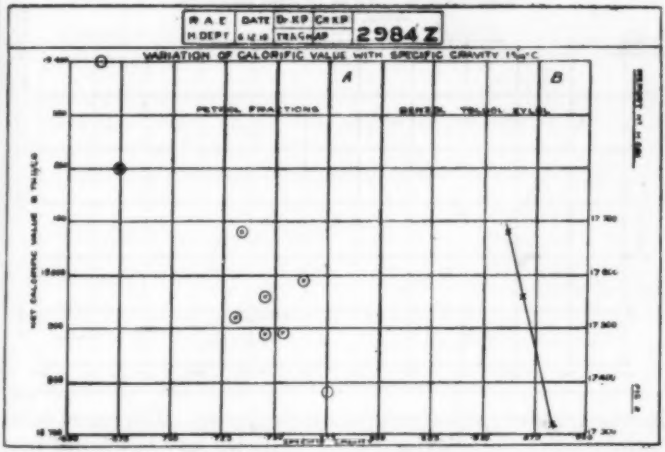
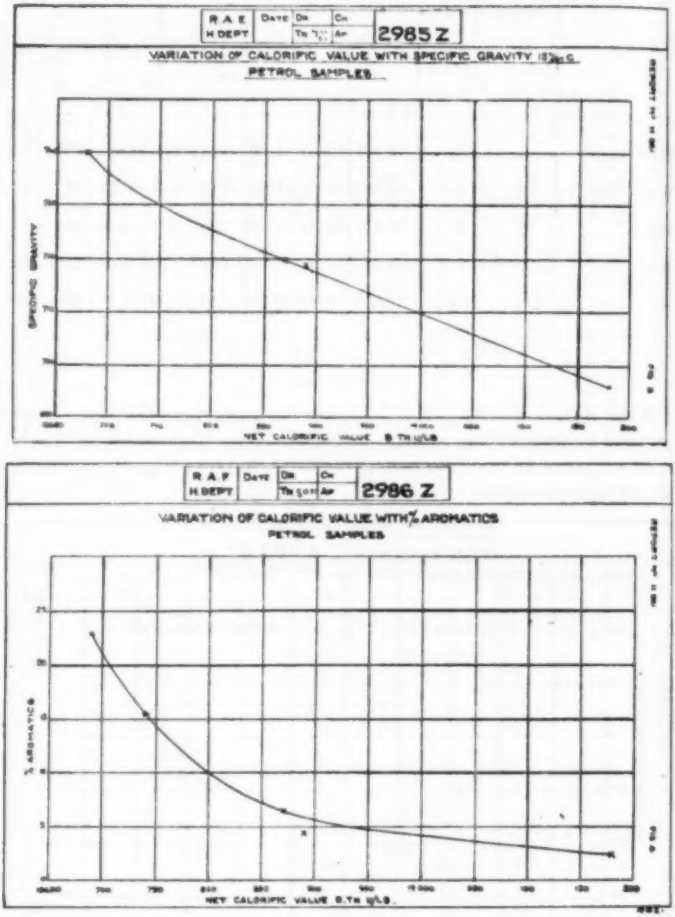


Fig. 2 (*a*) illustrates the general fall in calorific value with increased specific gravity; the points do not all lie in one straight line as the

fractions are not all pure paraffins but contain varying amounts of aromatic and other compounds. Fig. (*b*) illustrates the same point in connection with benzol, toluol and xylol, here the calorific value



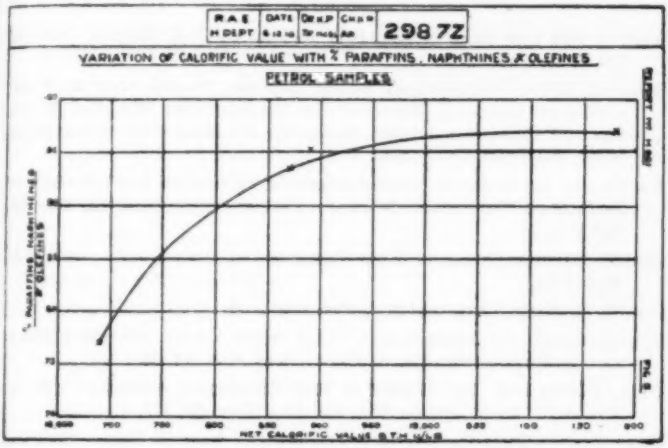
increases regularly with decreasing specific gravity. With regard to the petrol samples, the following general conclusion may be inferred from the foregoing table :—

1. The calorific values do not differ from each other by much more than 1%.

2. The calorific values increase with increased hydrogen content.

3. The calorific values decrease with increased specific gravity. This is to be expected as the lighter samples will contain the lower boiling hydrocarbons of higher calorific value (see Fig. 3).

4. The calorific values also decrease with increased percentage of aromatic bodies present. These hydrocarbons contain a lower hydrogen



percentage than the saturated paraffins, and could therefore be expected to lower the calorific value. The napthenes are intermediate in this respect (see Figs. 4 and 5).

A petrol may therefore be expected to have a high calorific value if:—

1. The specific gravity is low.
2. The hydrogen content is high.
3. The percentage of aromatic compounds is low.

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